PROJECT TITLE

Door the Explorer

STUDENT/TEAM INFORMATION

Team Name if any: **Team # on Canvas you have self-signed-up for:**	***Fries in The Baggers*** ***Team #:6***
Team member 1 *(Villar, Genesis Anne; gvillar7974@sdsu.edu):*	*Villar, Genesis Anne–* *gvillar7974@sdsu.edu* 
Team member 2 *(Gervacio, Steven; sgervacio7160@sdsu.edu):*	*Gervacio, Steven –* *sgervacio7160@sdsu.edu* 

ABSTRACT (15 points)

(Summarize your project (motivation, goals, system design and results). Max 300 words).

The Smart Door Alert System is an affordable, intelligent IoT-based security solution designed to detect unauthorized door access and provide real-time alerts and insights. This was motivated by personal experiences with shared living spaces and the high cost of traditional security systems. With our project, we aim to offer a practical and affordable alternative that enhances home security using sensor fusion, cloud analytics, email notification system.

The system features a multi-layered architecture. At the sensing layer, we have a lidar distance sensor that monitors door status, while secondary sensors are light and acceleration detectors. These provide the environmental context. These inputs are processed locally on a TTGO microcontroller, which performs initial data analysis and anomaly detection, and then uploads data to the AWS cloud server. Audible (buzzer) outputs provide immediate feedback if something has been tampered with. Data is securely transmitted via Wi-Fi to a cloud platform (AWS). This has a database and analytics engine to support historical trend analysis and pattern recognition. Ultimately, this system provides users with real-time alerts and predictive insights to improve security awareness. It offers an educational and cost-effective framework for building personalized smart home systems.

INTRODUCTION (15 pts)

Motivation/Background (3 pts)

(Describe the problem you want to solve and why it is important. Max 300 words).

Home security is a concern that many people have, whether that is someone breaking into their property or a roommate/family member snooping through their room. Considering that both of us grew up with multiple siblings, nothing is worse than searching your room relentlessly for something you know someone took without your permission, yet you don't know who the culprit is. This problem arises because of how expensive security cameras can be these days. The goal for this project is to make a cost-friendly device and teach you how to make your smart alert system. This project will mimic a home security system with enhanced capabilities. This is important because unauthorized entry can lead to theft and safety risks, but we wanted to prototype a device that goes beyond just simple intrusion detection. The real-time smart door system provides peace of mind to the user that their belongings are safe and not tampered with while providing intelligent insights based on real-time sensor data.

Project Goals (6 pts)

(Describe the project general goals. Max 200 words).

The goal of this project is to develop a cost-effective, user-friendly IoT-based Smart Door Alert System that enhances home automation and security. This system is designed to provide real-time awareness of door activity and pattern recognition/data analysis.

Our solution will incorporate multiple sensors, which are a light sensor, a lidar distance sensor, and an accelerometer sensor for identifying unusual events. These inputs will trigger real-time alerts via email and update a cloud-based dashboard for remote monitoring and visualization. The system aims to offer intelligent, adaptive security by analyzing historical data to distinguish between normal and suspicious behavior. By integrating edge processing with cloud analytics, the platform will remain responsive and efficient. The final product will not only serve as a security tool but also as an educational platform for exploring sensor fusion, IoT protocols, and data analytics applications in home environments.

Assumptions (3 pts)

(Describe the assumptions (if any) you are making to solve the problem. Max 180 words).

In developing the Smart Door Alert System, we make several key assumptions to guide the design and implementation process. First, we assume the system will be used in a single-user household environment where door activity is relatively low, making it feasible to track and analyze access patterns. In this case, it would be your room and not a common area where people come in and out, like the front of the house. We also assume stable Wi-Fi connectivity is available to ensure reliable cloud communication for real-time alerts and data analysis. Additionally, we assume the sensors will operate within standard environmental conditions, such as typical indoor lighting. Finally, we assume the system has access to consistent power, either through a wall outlet or regular battery charging, to support continuous operation.

SYSTEM ARCHITECTURE (20 pts)

(Describe the final architecture you have implemented listing sensors, communication protocols (Wi-Fi, BLE, ...), cloud services and user interfaces. Include a block diagram of the system. Max 300 words).

Our Smart Door Alert System incorporates a sophisticated multi-layered architecture for reliable intrusion detection:

- Sensing Layer: Three primary sensors (LiDAR distance sensor, light photocell, and LSM6DSO accelerometer) provide complementary data about door position, ambient conditions, and movement patterns.

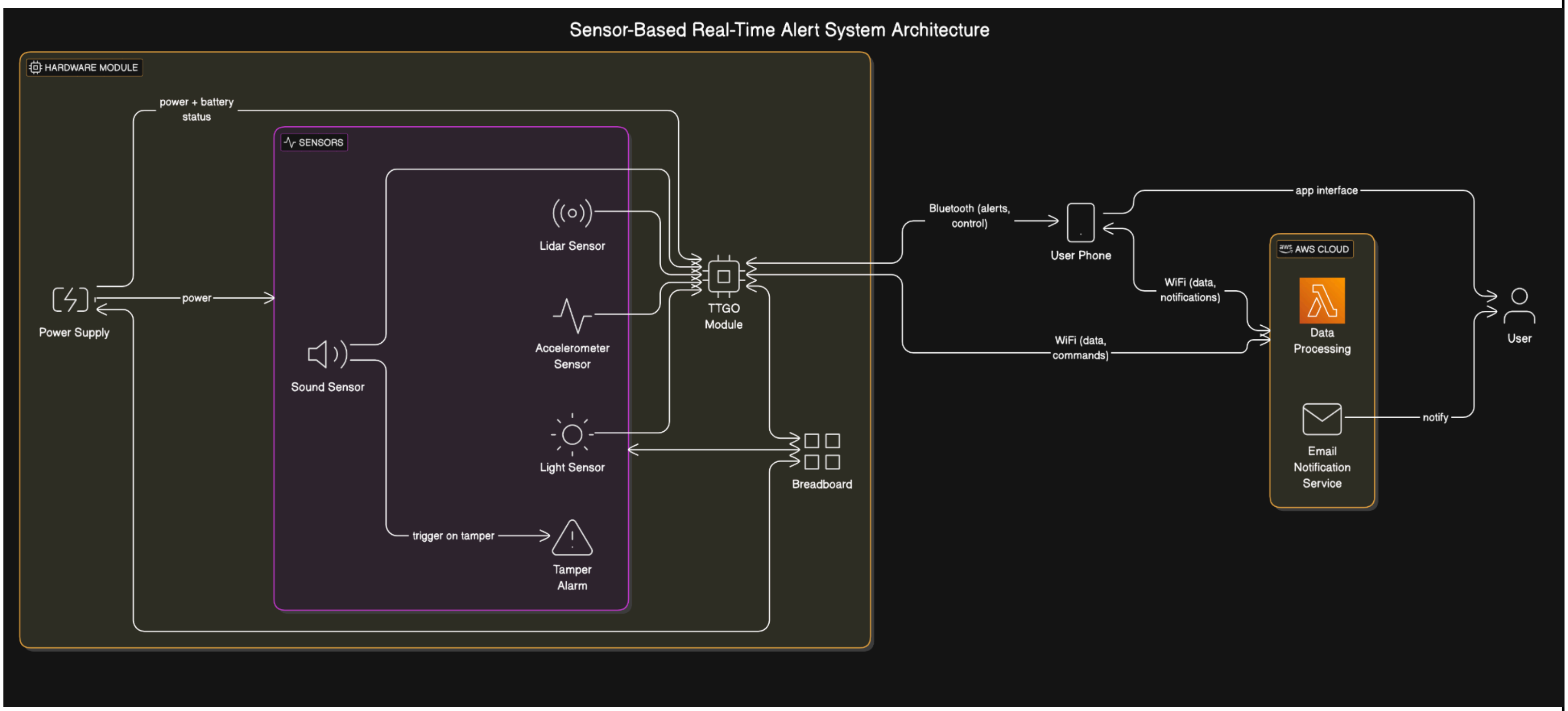
- Processing Layer: The TTGO microcontroller implements our enhanced security algorithm featuring:
  - Real-time pattern recognition to identify suspicious movement
  - Door velocity calculation and threshold analysis
  - Cumulative change detection across multiple sensor readings
  - Normal vs. suspicious activity differentiation

- The system features a 3-tiered alert hierarchy:
  - Level 1: Single sensor detecting anomalous readings
  - Level 2: Multiple sensors detecting potential intrusion OR slow door pattern detected
  - Level 3: Confirmed intrusion pattern with debounce protection

- Communication Layer: Dual connectivity through WiFi (for cloud integration) and BLE (for direct monitoring) ensures reliable alerts

- Cloud Services: AWS-hosted database and analytics engine providing historical pattern analysis and predictive insights, with real-time email alerting.
- Data Analytics Dashboard: Our system integrates with a custom AWS-hosted dashboard providing five key analytical perspectives:
  - 1. Alert Level Distribution: Visualizes the frequency of different security alert levels, providing insight into system sensitivity and overall security status.
  - 2. Sensor Value Trends: Tracks individual sensor readings over time to identify patterns, calibration needs, and environmental factors affecting door monitoring.
  - 3. Anomaly Detection: Automatically identifies unusual door activity patterns that don't match normal usage to catch potential intrusion attempts that might otherwise go unnoticed.
  - 4. Sensor Activity Correlation: Analyzes relationships between sensor activations to evaluate system efficiency and identify

which combinations most accurately detect specific types of intrusions.
    - 5. Hourly Alert Distribution: Shows security events throughout the day to identify temporal patterns, correlate with building occupancy, and recognize after-hours access attempts.
- This dashboard transforms raw sensor data into actionable security intelligence, allowing users to make informed decisions while reducing manual monitoring through intelligent visualization and pattern recognition.



FINAL LIST OF HARDWARE COMPONENTS (5 pts)

(Write the final list and quantity of the components you have included in your system)

Component/part	**Quantity**
Lidar (TF-LUNA) Range Finder Sensor Module	1
TTGO Lily Display	*1*
USB to Type C to USB cable	*1*
LSM6DS3 Accelerometer/Gyroscope	*1*
Light Sensor (Photoresistor or LDR)	*1*
Breadboard	*1*
Jumper Wires	*1*
Resistor Kit	*1*
Soldering Kit	*1*

Header Pins	*20+*
Capacitor Kit (assorted)	*1*
Buzzer	*1*

PROJECT IMPLEMENTATION (30 PTS)

Tasks/Milestones Completed (15 pts)

(Describe the main tasks that you have completed in this project. Max 250 words).

Task Completed	Team Member
Gathered all the needed equipment for the project ● Upon the approval of our project, prior to spring break, we've tasked ourselves with making sure the needed materials are prepped and ready for the building phase.	Steven Gervacio
Created test code and tested all components that are to be linked with TTGO Lily ● Successfully integrated and tested all the required components with the TTGO Lily board. After gathering the necessary hardware, we focused on verifying compatibility and functionality. Each sensor was individually connected and validated for accurate readings, and we experimented with various libraries to ensure optimal performance. Through this process, we confirmed that all sensors were properly interfacing with the TTGO Lily and reliably outputting the expected data.	Genesis Anne Villar
Created skeleton code for the alert system/ Data Analysis ● After successfully testing all hardware components, we began developing the skeleton code for our alert system. This initial framework outlines the necessary methods, key variables, and logical structure needed for sensor data processing and alert triggering. Alongside coding, we created a preliminary circuit design to ensure all components were properly wired and integrated. We implemented the data analysis module on the AWS cloud platform, enabling real-time data processing, storage, and visualization to enhance the system's intelligence and responsiveness.	Genesis Anne Villar
Start and create the Wi-Fi connectivity and cloud integration/ Presentation & Report	Steven Gervacio

• After implementing our alert system's initial version, we established Wi-Fi connectivity and began cloud integration. We set up an AWS server, similar to our approach in Lab 3, to handle real-time data uploads and remote monitoring capabilities. This setup allowed seamless communication between our device and the cloud, enabling functions such as data logging, analytics, and email notifications. Additionally, the progress made was important for our final presentation and report by providing concrete system functionality and data visuals to support our results.	
Enhanced Intrusion Detection Algorithm Development • Implemented sophisticated pattern recognition to differentiate between normal door usage and suspicious activity. In addition, we developed velocity-based analysis to detect slow/sneaky door opening attempts. This new, improved multi-tiered alert system with debounce protection helped minimize false positives that we were consistently having issues with. Also, an integrated persistent state tracking was implemented across sensor readings for improved reliability.	Genesis Anne Villar

Challenges/Roadblocks (5 pts)

(Describe the challenges that you have faced and how you solved them if that is the case. Max 300 words).

During the hardware setup, we had some trouble with the sensor integration, namely with the LiDAR and the LSM6DS3. This was due to issues with communication and calibration difficulties. Since we set up LSM6DS3 through I2C in Lab4 and the LiDAR could also be connected to the TTGOLily through I2C, we thought both could share the same pin connections. We found out through trial and error that there was too much noise disruption between the two sensors which was causing the TTGOLily to completely shut down every time. We separated these two sensors by using the LiDARs default communication method, UART, while keeping the LSM6DS3 I2C. The light sensor also gave us a few issues with connectivity and reading.

In the alert system phase, one significant challenge we faced was designing an effective algorithm to distinguish between normal door opening and suspicious activity. Initially, our system generated false alarms during regular use while sometimes missing slow intrusion attempts. We solved this by implementing:

1. Door velocity analysis that calculates opening speed over time
2. Pattern recognition that identifies suspicious movement signatures
3. A debounce timer system that requires consistent suspicious readings before triggering high-level alerts
4. Normal activity detection that automatically suppresses alerts during recognized regular usage patterns

These improvements dramatically reduced false positives while increasing detection accuracy for actual intrusion attempts.

Cloud integration could bring potential Wi-Fi instability, risking data loss or delayed alerts. We have not encountered this yet, but will keep an eye out, since Amazon's AWS service contacted us that we were using up 89% of our cloud storage usage. The data analysis part was a bit challenging to set up along with the email notification, but overall was able to work through it by installing a new Flask module and using HTML and JSON to set up the dashboard.

Tasks Not Completed (5 pts)

(Describe the tasks that you originally planned to complete but were not completed. If all tasks were completed, state so. Max 250 words).

We believe that all tasks planned for this project were successfully completed. We successfully integrated and tested multiple sensors, including a LiDAR range finder, light sensor, and accelerometer, along with an alert buzzer. The TTGO board was used as the central microcontroller, with all components properly powered via a regulated power supply and breadboard layout.

We established reliable connectivity through both Wi-Fi and Bluetooth, enabling real-time communication with the user's smartphone and remote access to system data. The email notification system was implemented and tested to alert users upon detecting potential abnormal door events. In addition, we achieved full cloud integration using AWS services, where sensor data was stored and visualized.

Data analytics features were implemented to identify patterns in door activity, allowing for intelligent recognition of potential security threats. The system also included a basic predictive component to classify activity as normal or abnormal, with different tier levels of alarms. All planned goals, including hardware setup, connectivity, alerting, cloud storage, and data visualization, were completed successfully and demonstrated in our final implementation.

WEAK POINTS / FUTURE WORK (15 pts)

(Mention at least two points of your project that have room for improvement. These points can be additions to the existing project setup (components) or improvements to the current implementation. Max 200 words).

One area for improvement is our alert system code because the current draft that we intended to have lacks modularity and would potentially make future updates harder to manage. We could optimize the rough draft of the code in the alert system and break it down, and make it easier to read.

Another opportunity lies in improving the physical design. While our current prototype works well on a breadboard, a custom and durable 3D-printed enclosure would make the device more practical and appealing for everyday use, especially if scaled for mass production. This would improve not only durability but also user experience and aesthetic value.

Power efficiency is another area worth enhancing. By integrating a battery level monitor and implementing sleep modes or low-power states for sensors and the microcontroller, we could significantly improve energy efficiency and extend battery life.

SOURCE CODE (25 pts)

Please include a link to the source code of your project. A link to a repository (like [GitHub](https://github.com)) is preferred.

https://github.com/stevengervacio/CS-596-IOT-FINALPROJECT