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BAILEY COLLEGE OF ENGINEERING & TECHNOLOGY

Semester Project #2: Gate Entry Security System

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ECT 308: IoT Microcontrollers

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Abstract

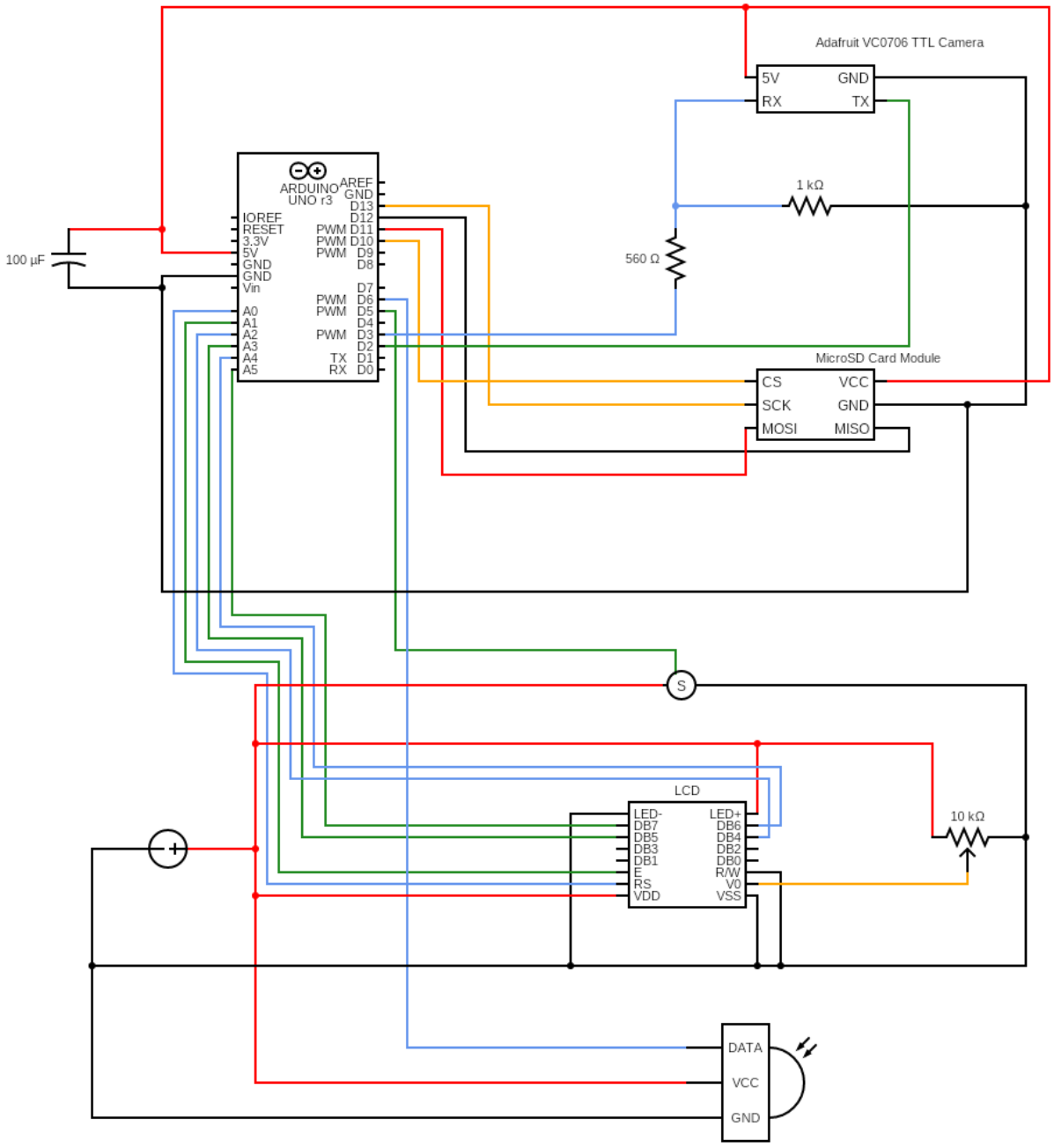
This project involved the development of a microcontroller-based gate entry security system using an Arduino platform. The goal was to detect and validate individuals requesting access using a combination of motion detection, image capture, and infrared (IR) remote ID verification. The system was designed to trigger a TTL serial camera to capture a photo when motion was detected, store the image to a microSD card, and prompt the user via an LCD screen to present an access code. An IR receiver was used to validate input from a remote control against authorized codes. Upon successful verification, a servo motor opened a simulated gate for a predefined duration. The LCD display updated at each critical stage, including motion detection, ID request, access granted or denied, and status reset. Although initial project instructions included web-based moderator verification and DC motor relay control via ThingSpeak, these were not implemented in the final version. The completed system demonstrates a functional prototype for low-cost, embedded access control using multiple hardware interfaces and real-time input processing.

Keywords: Arduino, security system, IR remote, microSD, TTL camera, servo motor, motion detection, LCD display

Gate Entry Security System

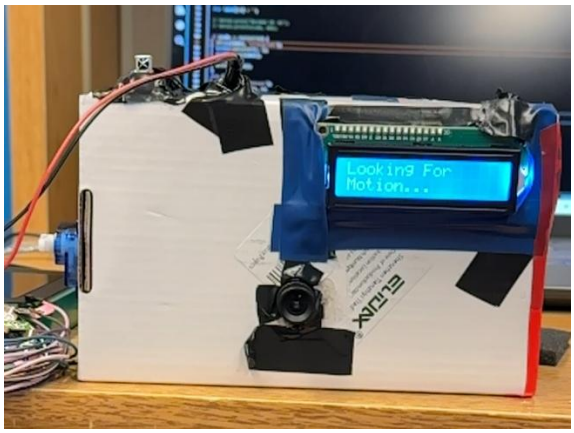
This project presents the development of a microcontroller-based gate entry security system designed to demonstrate practical applications of embedded systems in access control environments. The system is implemented using the Arduino platform and incorporates a range of components including a TTL serial camera, infrared remote input, servo motor, microSD card storage, and a character-based LCD interface. The purpose of the system is to autonomously monitor for motion at a controlled entry point, capture a photographic record of activity, and authenticate individuals through coded input via an infrared remote. Upon successful identification, the system simulates gate access by activating a servo-driven mechanism. Throughout the development process, attention was given to hardware-software integration, signal reliability, and power stability. This paper outlines the project objectives, system design, implementation methodology, and testing procedures that support the creation of a functional and efficient embedded access control prototype suitable for educational and applied research setting.

Schematics

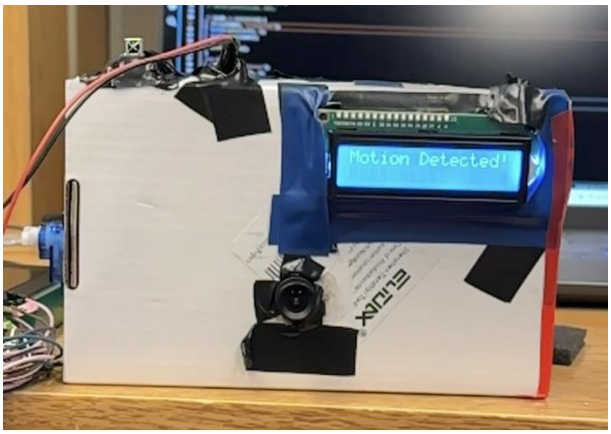

Adafruit VC0706 TTL Camera
5V
GND
RX
TX
1 kΩ
560 Ω
100 µF
ARDUINO UNO r3
AREF
GND
D13
D12
PWM D11
PWM D10
PWM D9
D8
D7
PWM D6
PWM D5
D4
PWM D3
D2
TX D1
RX D0
IOREF
RESET
3.3V
5V
GND
GND
Vin
A0
A1
A2
A3
A4
A5
MicroSD Card Module
CS
SCK
MOSI
VCC
GND
MISO
S
LCD
LED-
DB7
DB5
DB3
DB1
E
RS
VDD
LED+
DB6
DB4
DB2
DB0
R/W
V0
VSS
10 kΩ
DATA
VCC
GND

Project Images

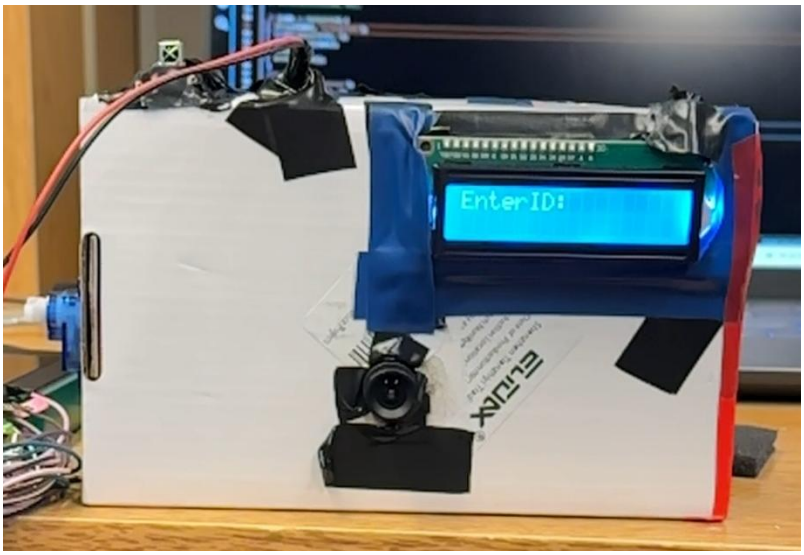
Looking For Motion



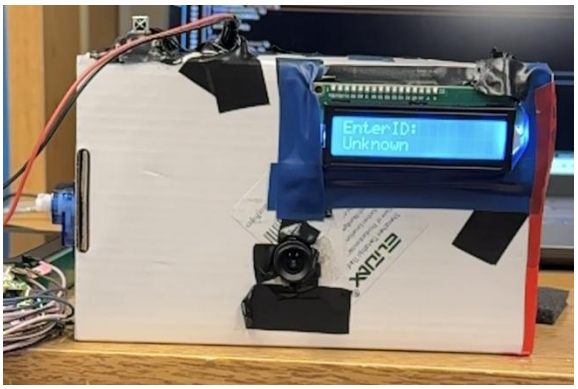
Motion Detected



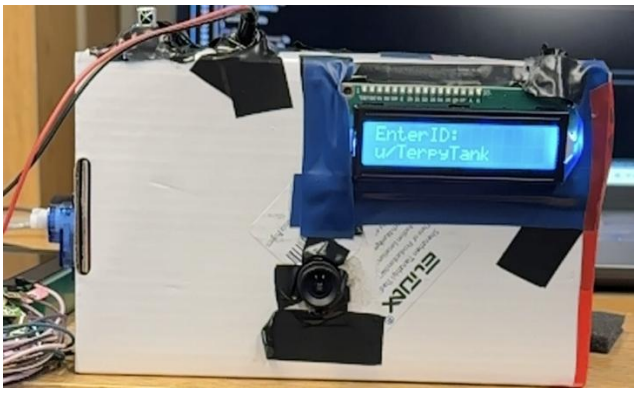
EnterID:



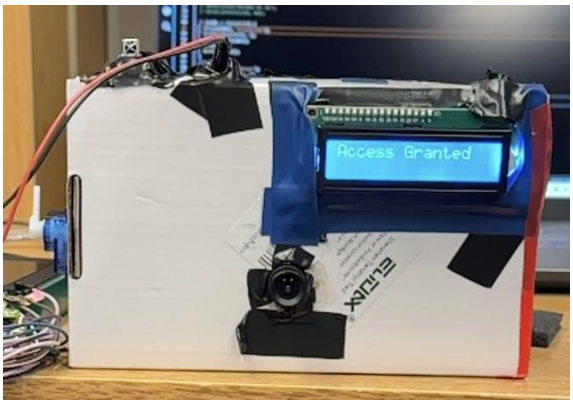
Unknown User



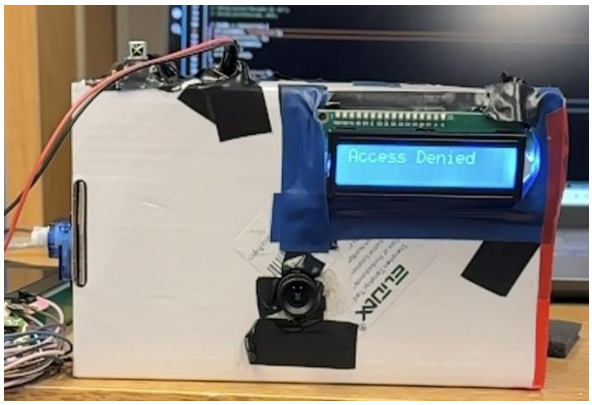
Known User



Access Granted



Access Denied



Objectives for the Security Camera and System

The objective of this project was to design and implement an Arduino-based gate entry security system capable of detecting motion, capturing images, and verifying identity using an infrared (IR) remote. The system aimed to automate the process of monitoring and granting access to a secure area using a combination of sensors and peripheral devices. Specifically, the project required the setup of a TTL serial camera to detect motion and capture images, a microSD card module to store those images, and a 1602 LCD screen to notify the user of system status and access prompts. Upon motion detection, the system would prompt the user to provide identification via an IR remote. If the transmitted IR code matched a predefined authorized value, a servo motor would rotate to simulate gate opening, then return to its original position after a brief delay. The LCD would update at each stage, displaying messages such as “Motion Detected,” “Enter ID,” and either “Access Granted” or “Access Denied.” Although the initial project requirements included integration with a web platform (ThingSpeak) for moderator verification and online status monitoring, this feature was not implemented in the final version. Similarly, plans to use a DC motor and relay for physical gate control were replaced with a servo motor simulation. The project successfully demonstrated a functional and compact security access system using real-time sensor input and output control via a microcontroller.

Algorithm for the Security Camera and System

The algorithm for the gate entry security system was designed to coordinate multiple modules in a sequential process triggered by motion detection. The program begins by initializing all connected peripherals, including the TTL camera, LCD display, servo motor, SD card module, and IR receiver. Once initialized, the system enters an idle loop where the LCD displays a message indicating that it is actively scanning for motion. When the camera detects motion, the LCD is updated to notify the user, and a snapshot is immediately taken and saved to the microSD card with a unique filename. Following image capture, the system prompts the user to enter an ID via an IR remote. The IR signal is decoded, and the received code is compared to pre-approved hexadecimal values stored in the program. If the input matches a recognized code, the LCD displays the associated username and confirms access permission. The system then activates the servo motor to rotate to an open position, simulating the gate opening, maintains the position for five seconds, and returns the servo to its original state. If the IR code is not recognized, the LCD displays an “Access Denied” message, and no further action is taken. Each operation is accompanied by timed LCD updates to ensure users are informed throughout the sequence.

1) **System Initialization**
    a) Begin serial communication for debug output.
    b) Initialize the LCD screen and set the cursor position.
    c) Attach the servo motor to its control pin and move it to the closed gate position.
    d) Initialize the microSD card and prepare it for file operations.
    e) Configure the TTL camera settings, including image resolution and motion detection.
    f) Enable the IR receiver for capturing input from an IR remote.

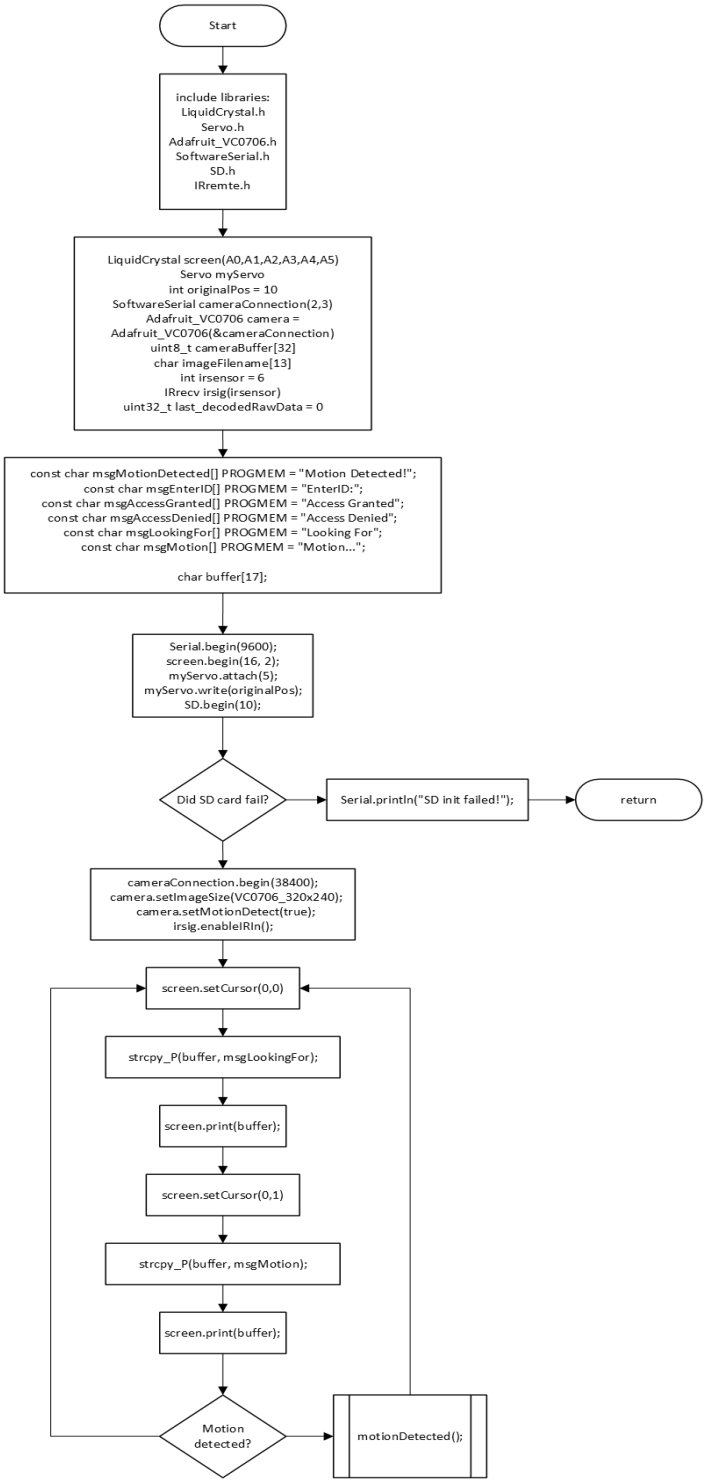
2) **Main Monitoring Loop**
    a) Display a message on the LCD indicating that the system is actively scanning for motion.
    b) Continuously check the camera for a motion detection signal.
    c) If motion is detected, proceed to the next steps.
3) **Motion Response Routine**
    a) Disable motion detection temporarily to avoid interference during image capture.
    b) Display a "Motion Detected" message on the LCD.
    c) Capture a still image using the TTL camera and save the file to the SD card with an automatically incremented filename.
    d) Prompt the user to input an access ID using the IR remote.
    e) Wait for and decode the IR signal input.
4) **Access Verification**
    a) Compare the decoded IR code against authorized values.
    b) If the IR code matches a predefined valid ID (e.g., 0xE916FF00), display the user label, show an "Access Granted" message, and trigger the servo motor to simulate gate opening for a predefined time interval.
    c) If the IR code does not match, display an "Access Denied" message and do not activate the gate mechanism.
5) **System Reset**
    a) Clear the LCD screen after each operation.
    b) Re-enable camera motion detection.
    c) Return to the main monitoring loop to await the next motion event.

Hardware Overview

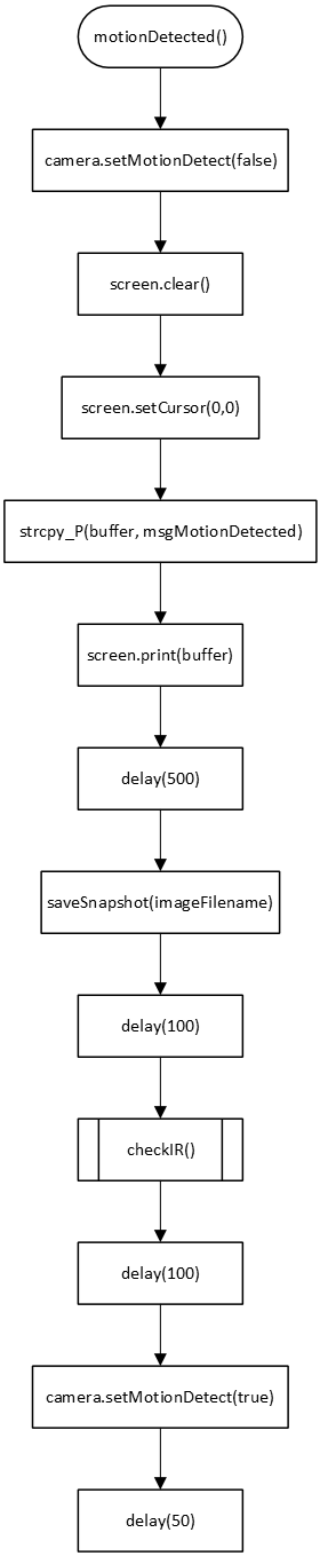
- Elegoo UNO R3
- Jumper Wires
- SD Card Module
- 8 GB SD Card
- 10 KΩ Potentiometer
- Servo Motor
- IR Sensor
- IR remote
- Adafruit VC0706 TTL Camera
- 100 µF Capacitor
- 1 KΩ Resistor
- 5 V DC Power Supply
- LCD 1602 Module
- Breadboards
- Arduino IDE

Flowchart and Code Description

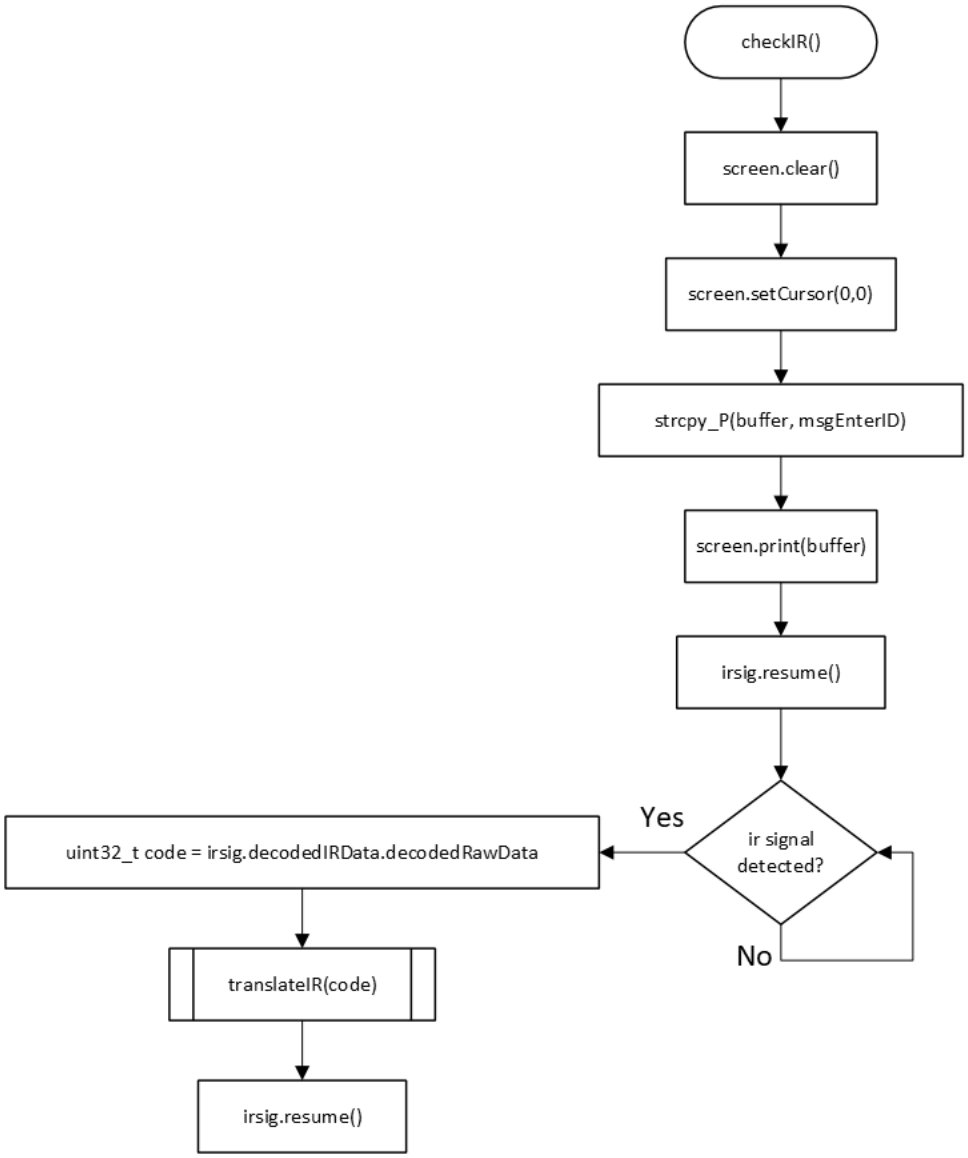
Main Setup & Loop



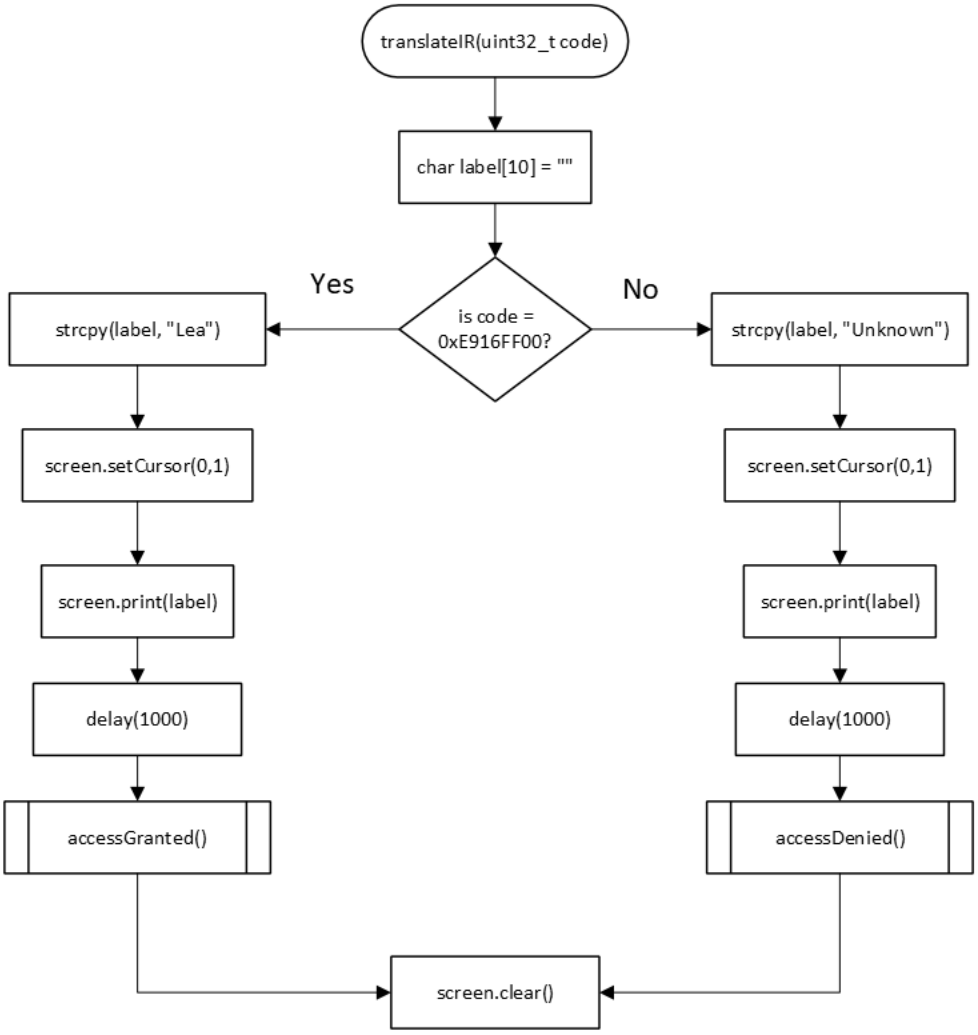
motionDetected() Function



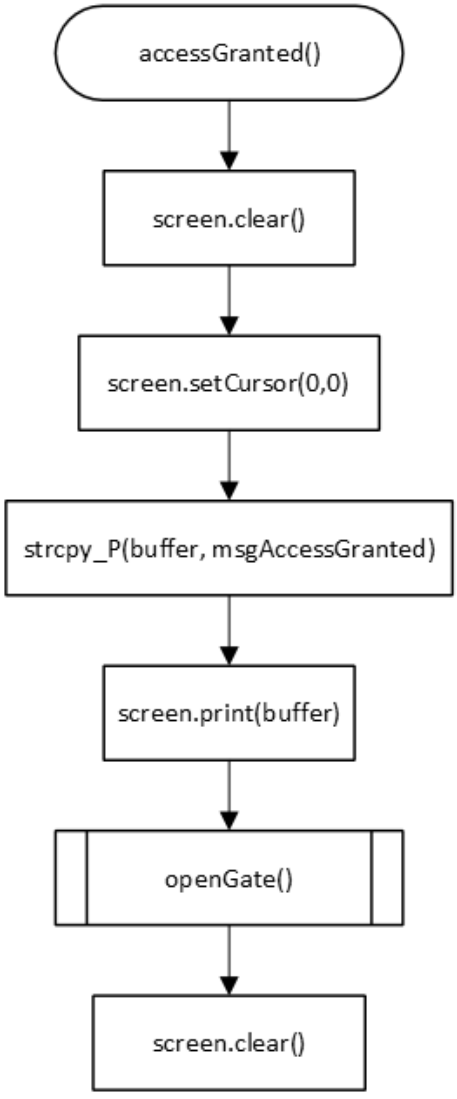
checkIR() Function



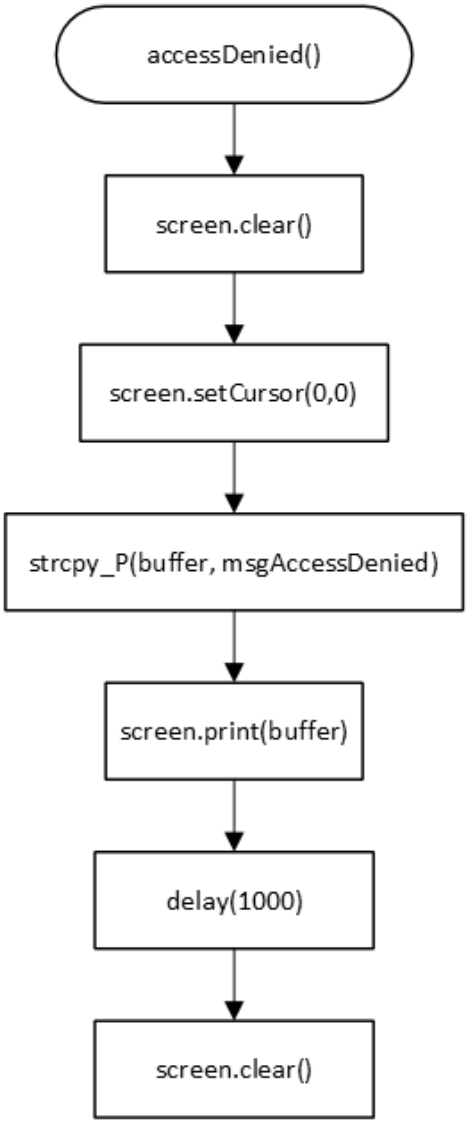
translateIR() Function



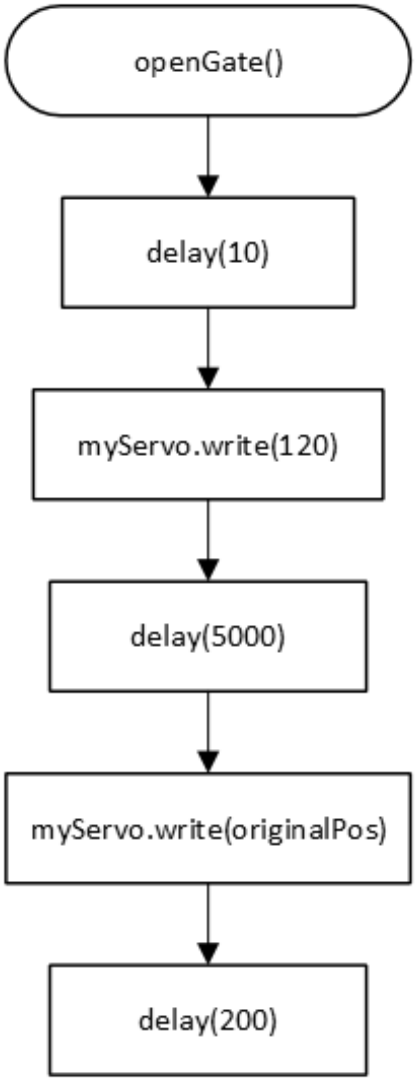
accessGranted() Function



accessDenied() Function



openGate() Function



Test and Debug

Extensive testing and debugging were required throughout the development of the Gate Entry Security System to ensure proper functionality of all integrated components. Challenges emerged during the interfacing of the TTL serial camera, IR receiver, SD card module, LCD display, and servo motor. Each issue was resolved through step-by-step troubleshooting, code refinement, and hardware verification.

One of the initial challenges encountered was establishing reliable serial communication between the Arduino and the VC0706 TTL camera module. Serial communication requires careful matching of transmit (TX) and receive (RX) lines, which are unidirectional. Early wiring attempts incorrectly connected TX-to-TX and RX-to-RX between the Arduino and camera, which resulted in failed camera initialization. To resolve this, the TX pin of the Arduino was connected to the RX pin of the camera, and the RX pin of the Arduino was connected to the TX pin of the camera, following standard UART protocol. Because the Arduino UNO has only one hardware serial port, which was occupied by the USB connection for debugging, a SoftwareSerial interface was used to create a second serial connection dedicated to the camera. Pins D2 and D3 were assigned for RX and TX respectively, allowing the camera to operate on its own serial channel and eliminating communication interference with the serial monitor.

SD card integration presented a different set of issues related to memory management and initialization timing. In an effort to reduce SRAM usage, the standard SD library (SD.h) and its dependent File class were modified to strip out unused functions. However, this caused compile-time errors because critical virtual functions such as read() and peek() were removed, breaking compatibility with the Arduino core libraries. After restoring these methods, the SD card still failed to initialize during runtime. Diagnostic serial output revealed that SD.begin(cs) returned false, indicating a hardware or communication issue. This was ultimately traced to the order of peripheral initialization in the setup() function. The SPI bus is shared by both the SD card module and the camera library, and initializing the

camera before the SD card caused bus contention. Reordering the initialization by calling SD.begin(10) before starting the camera resolved the conflict and allowed the SD card to be accessed reliably.

Further improvements were made to ensure compatibility with FAT32 filesystems used on microSD cards. FAT32 requires file names to be in uppercase and follow the 8.3 format. To accommodate this, image filenames were programmatically converted to uppercase using a custom strupr() function before being passed to SD.open(). This step ensured that filenames like “IMG001.JPG” were correctly recognized by the filesystem, avoiding cases where lowercase names silently failed to create files. With these changes in place, the system successfully captured images upon motion detection and saved them to the SD card under incremented filenames.

The camera save routine was enhanced to reliably store images. This involved looping through the picture data using 32-byte buffer chunks and ensuring the camera’s motion detection feature was temporarily disabled during the save operation. For the IR remote, decoding issues were identified when repeated button presses generated identical values. These were resolved by properly resuming the receiver after each signal and ensuring each code was correctly parsed. To minimize memory usage, LCD display messages were stored in program memory using PROGMEM, and functions like strcpy_P were used to retrieve them efficiently.

Servo motor jitter was identified during testing, often causing unpredictable motion after the gate access routine. The issue was traced to voltage dips caused by current draw from the servo. Solutions included recommendations to use decoupling capacitors across the power and ground lines, or to power the servo from a separate source with a shared ground. Additional testing confirmed that improper grounding or shared power lines contributed to erratic behavior.

LCD initialization required precise timing to avoid display corruption. The custom ShiftedLCD library used SPI to communicate with a 74HC595 shift register driving the 1602 LCD in 4-bit mode. This approach initially offered the benefit of conserving digital I/O pins by shifting data through serial-to-parallel conversion. However, it required detailed analysis of the shift register's pin behavior and a firm

understanding of how to perform bitwise operations to control specific LCD lines such as RS, Enable, and data bits D4 through D7. Extensive research was conducted to break down how the LCD's command structure maps to 4-bit operations, and how those bits must be clocked through the shift register using SPI.transfer along with proper latch and pulse timing. Despite significant effort in reverse-engineering the instruction set and timing sequence, persistent display instability and difficulty troubleshooting SPI timing led to the shift register approach being abandoned. Instead, the LCD was connected directly to the Arduino's analog pins A0 through A5, allowing for more straightforward parallel communication. This change improved reliability and reduced debugging complexity, especially during the critical initialization phase which follows the HD44780 standard sequence of function set, display control, and entry mode commands.

Later in the development process, memory constraints caused SRAM overflow errors due to the use of dynamic String objects and large buffers for camera and SD card operations. These were corrected by switching to fixed-length char arrays, reducing buffer sizes, and streamlining code. After implementing all necessary optimizations and corrections, the system successfully completed its intended functions: detecting motion, displaying messages, capturing and storing images, and validating user access using the IR remote. Each fix was confirmed through LCD feedback and serial monitor output during test cycles.

Conclusion

The Gate Entry Security System project achieved its primary objective of creating a reliable Arduino based access control prototype that integrates motion detection, image capture, identity verification, and mechanical actuation. The final design successfully combined multiple peripherals including a TTL serial camera, LCD screen, IR receiver, microSD card module, and both a servo motor and a DC motor via relay control to simulate real world security entry operations. Careful attention was given to hardware timing, memory optimization, and electrical stability. Through extensive debugging and design revisions, the system was refined to handle motion triggered events, validate authorized users via IR codes, capture and store photographic records, and activate a physical gate mechanism using both servo and DC motors. The experience emphasized the importance of modular code structure, hardware software synchronization, and thoughtful peripheral interfacing. Future improvements may include wireless data upload, encrypted access logs, and mobile app control for enhanced functionality and scalability.

References

Monk, S. (2016). *Programming Arduino: Getting Started with Sketches* (2nd ed.). McGraw Hill.

Seneviratne, P. (2015). *Internet of Things with Arduino Blueprints: Develop Interactice Arduino-Based Internet Projects with Ethernet and Wi-Fi* . Packt Publishing.

Footnotes

Figure 1.

Complete wiring schematic of the project

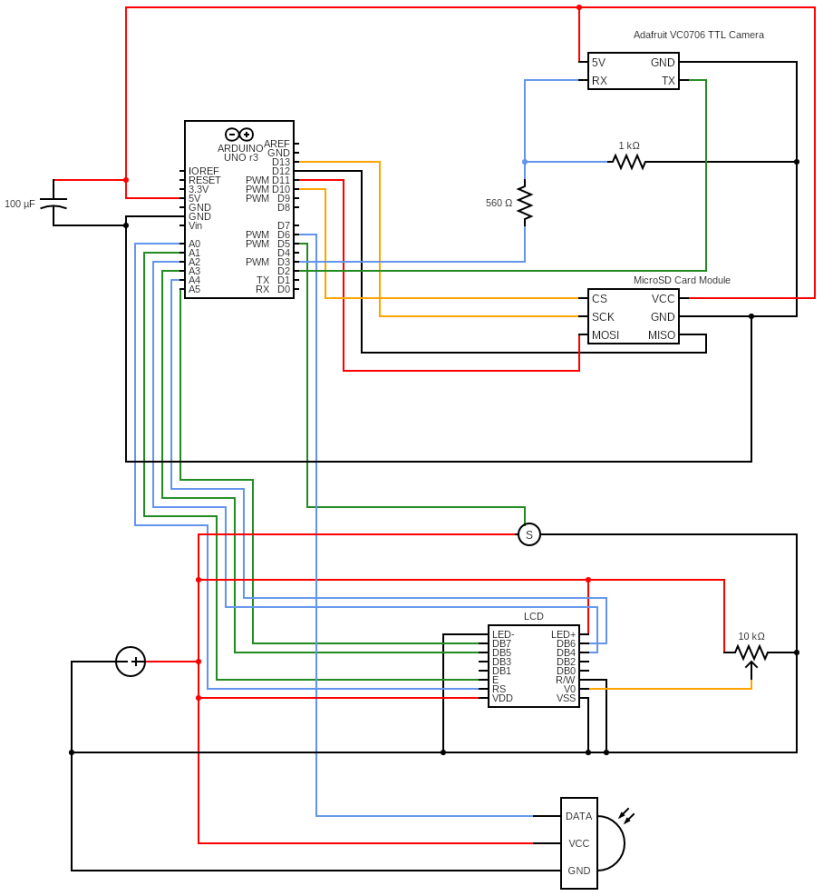


Figure 2.

Image of completed project demonstrating LCD prompt is informing user that the device is actively looking for motion. This step is only taken if the SD card has successfully initialized.

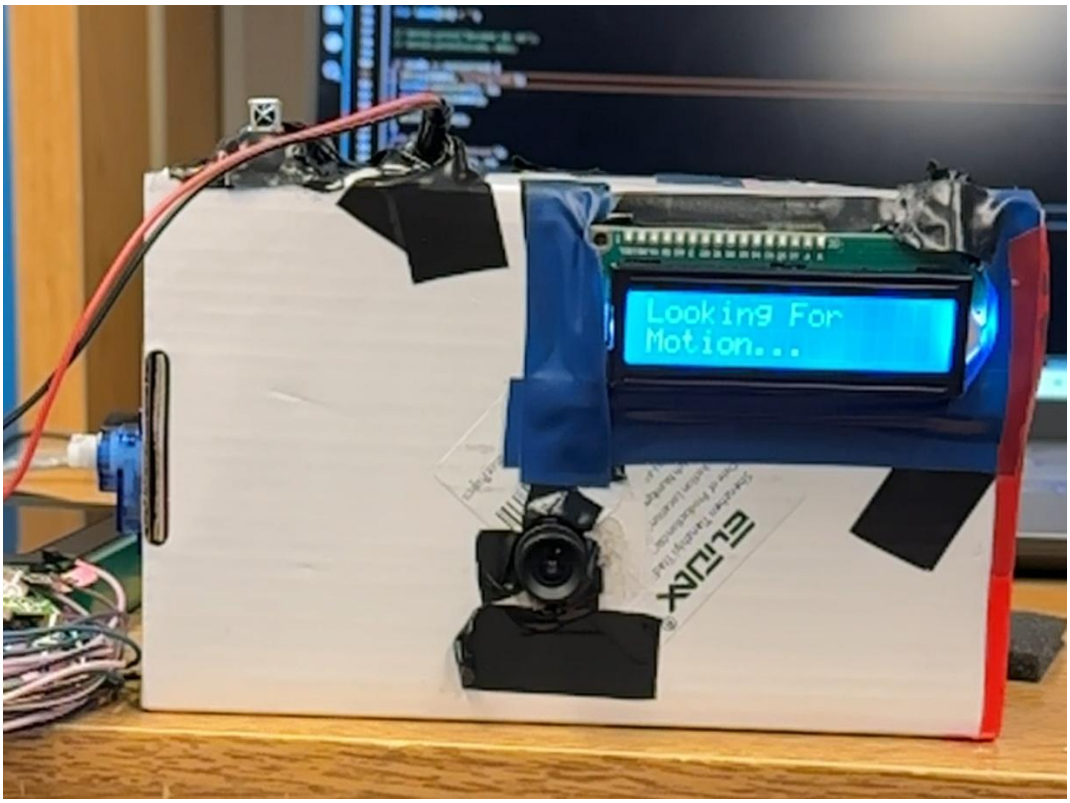


Figure 3.

Image of completed project demonstrating LCD prompt is informing user that the device has detected motion.

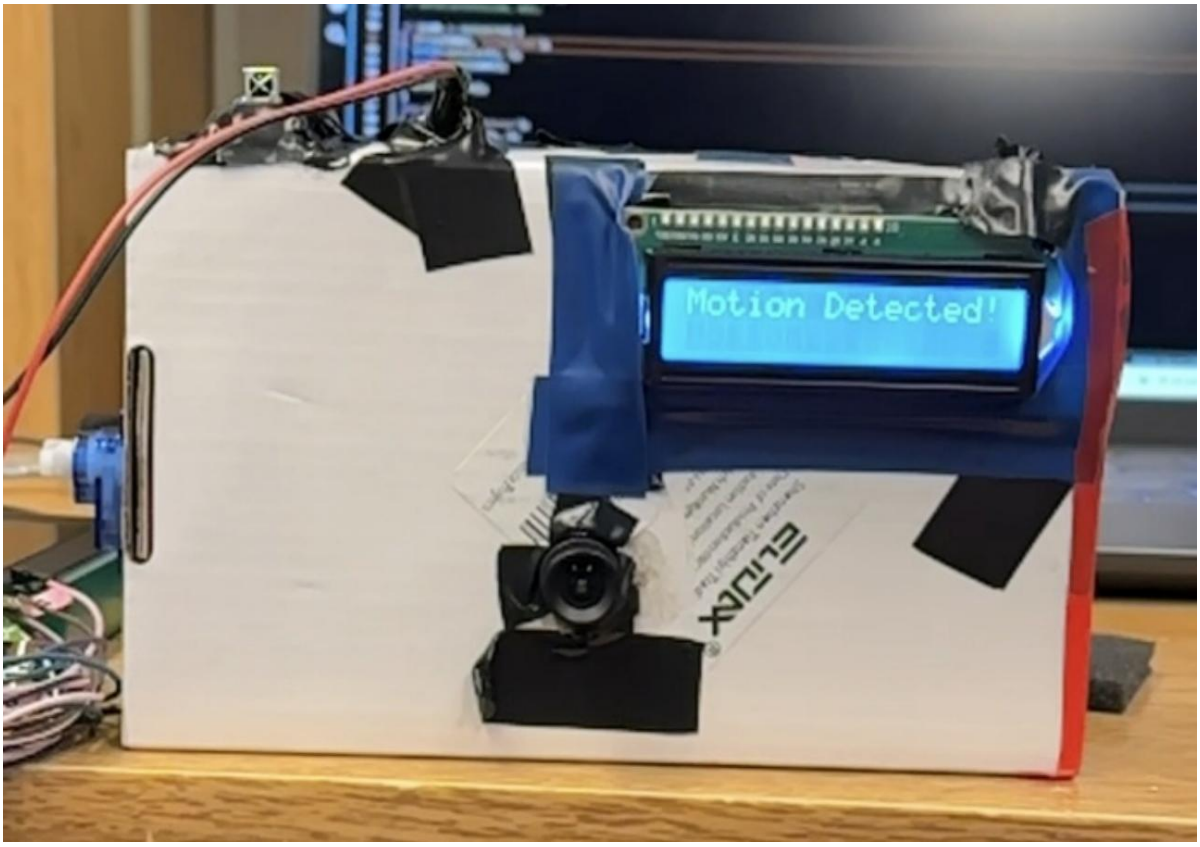


Figure 4.

Image of completed project demonstrating LCD prompt is informing user that the device is actively looking for an IR signal to interpret.

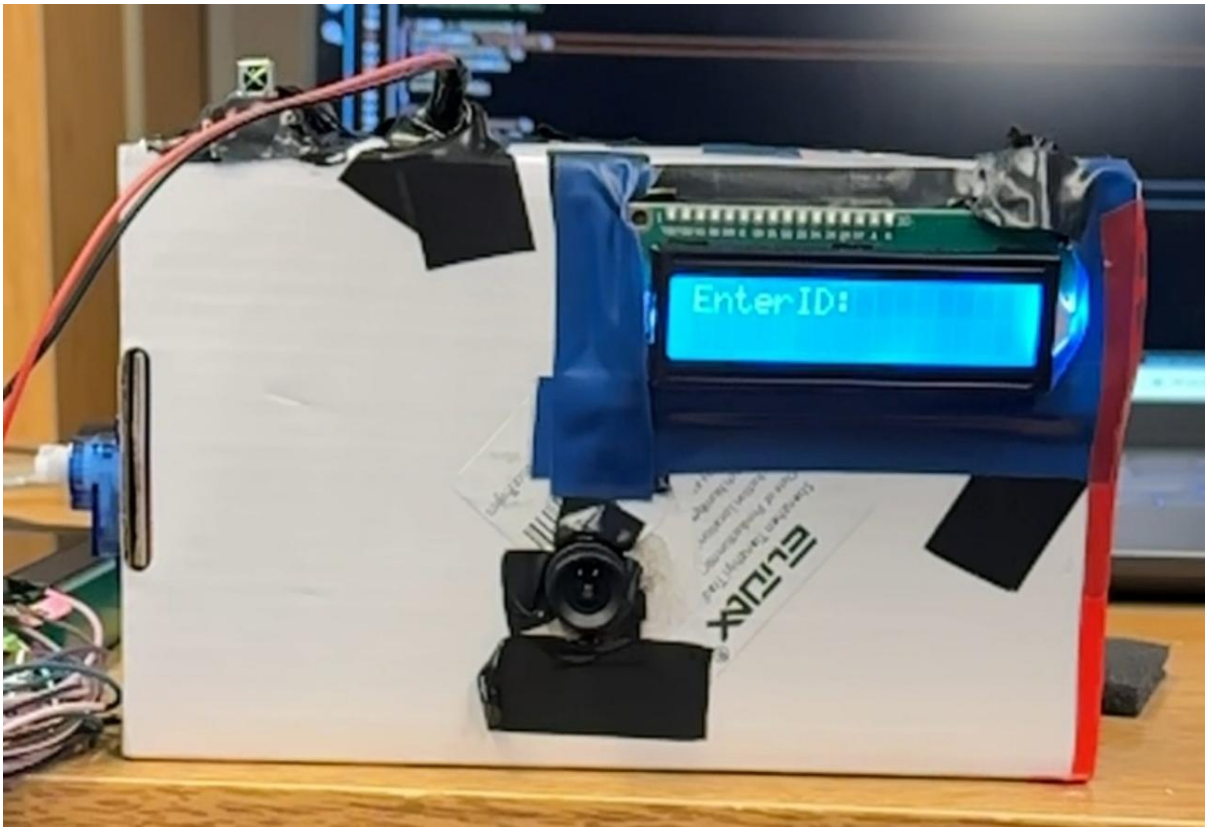


Figure 5.

Image of completed project demonstrating LCD prompt is informing user that the device did not recognize the user.

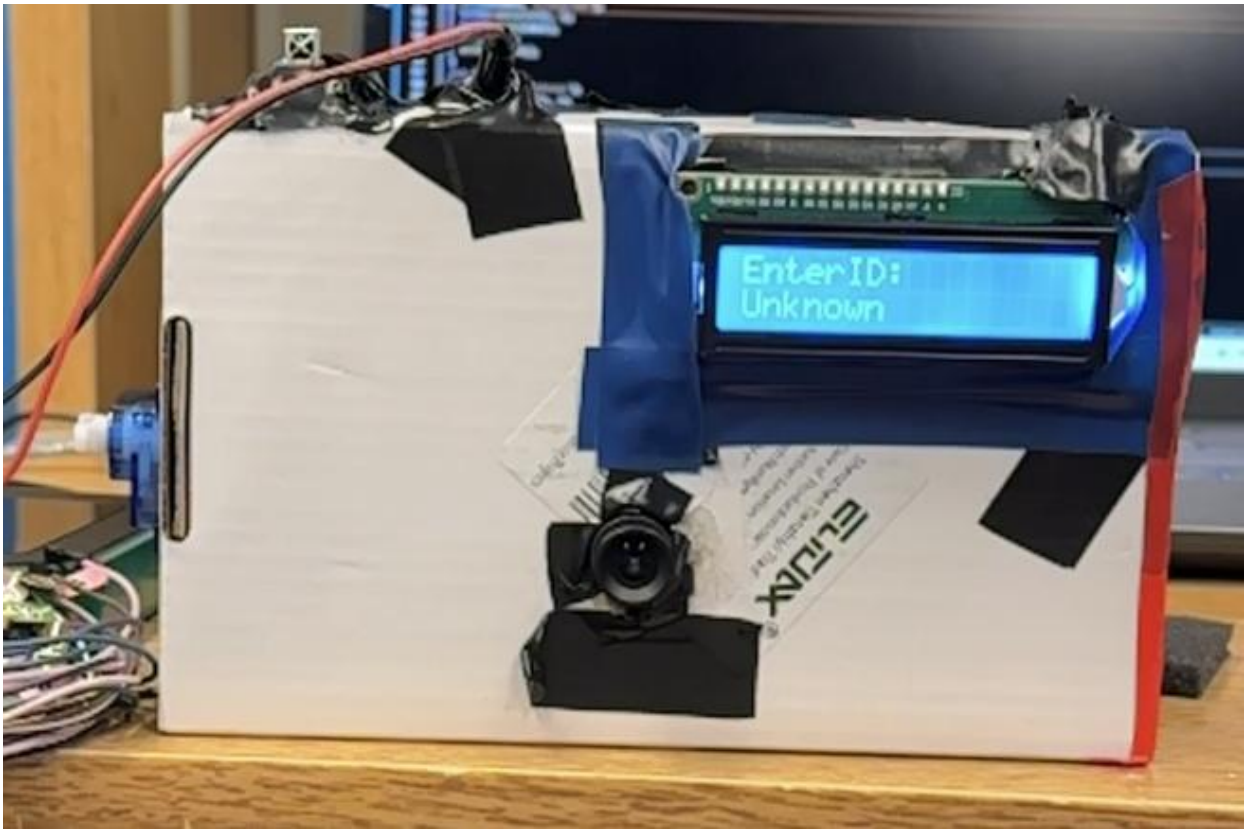


Figure 6.

Image of completed project demonstrating LCD prompt is informing user that the device recognized the user.

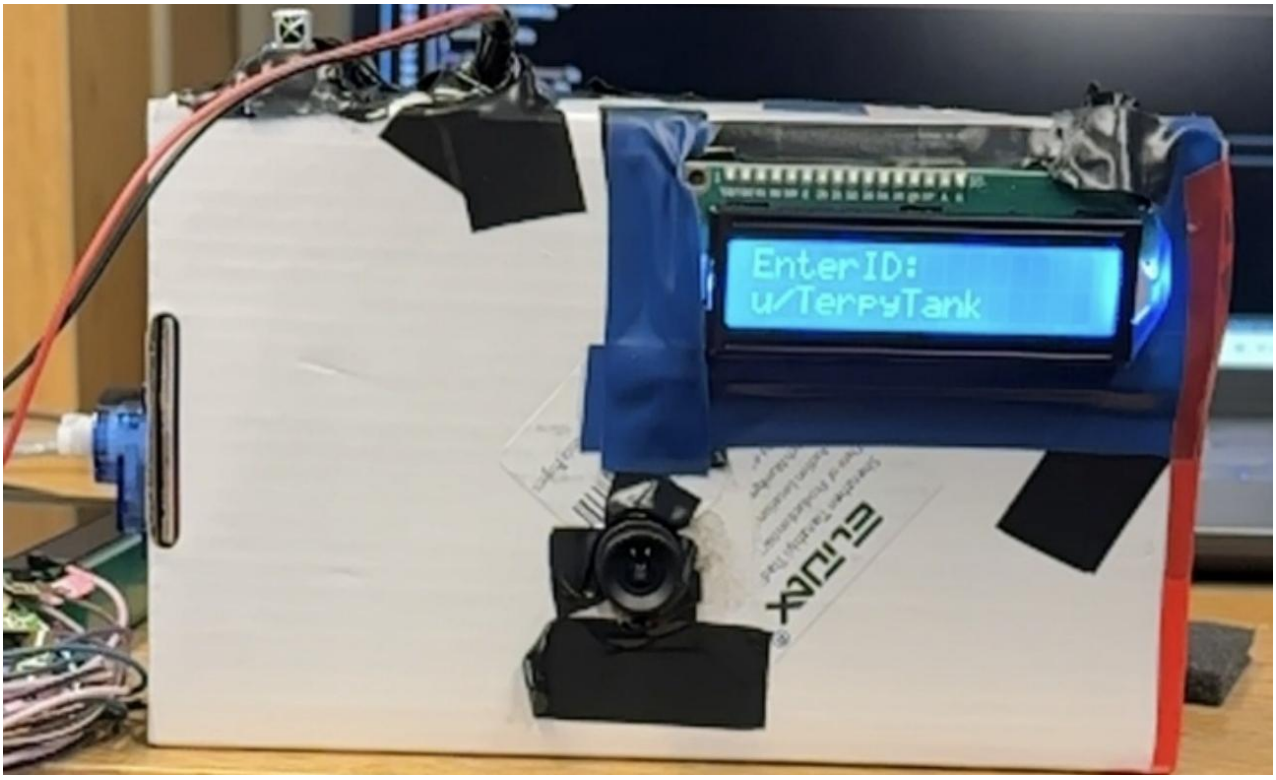


Figure 7.

Image of completed project demonstrating LCD prompt is informing user that the device has granted access and turned the servo motor 90 degrees.

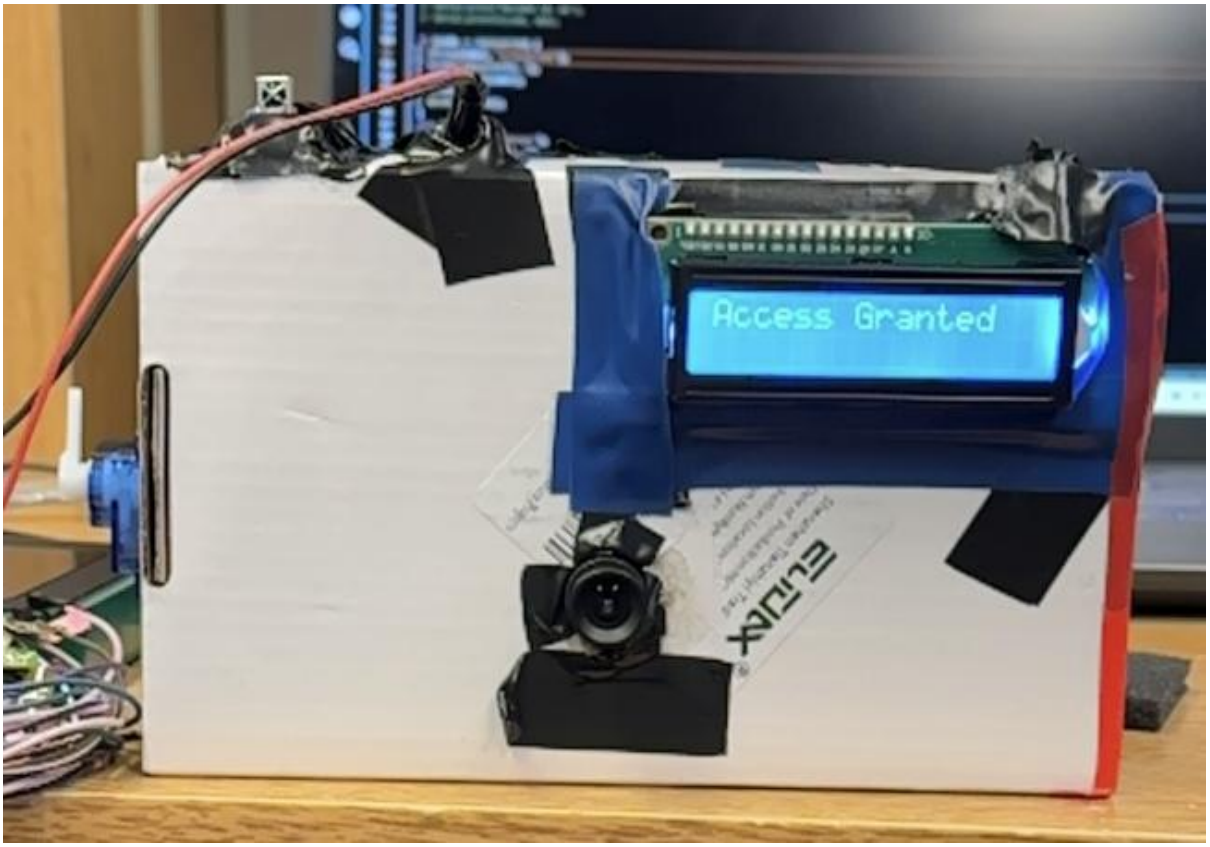


Figure 8.

Image of completed project demonstrating LCD prompt is informing user that the device will not grant access to the unknown user and so the servo motor does nothing.