CM10194 Coursework 2 Write up

Introduction

In the UK, burglary is one of the most common crimes committed, with a ‘burglary occurring once every 106 seconds on average’ (Josh Jackman, 2020). One of the biggest reasons for this is that ‘63% of burglaries happen in homes without any basic security’ (Josh Jackman, 2020). On top of the loss of possession, burglary also brings an emotional toll on victims, causing many to go through constant anxiety and stress in their own homes. Many students seek to live in houses during university and are targeted a lot due to the students’ unfamiliarity with renting a house (i.e. security). It was reported that ‘⅓ of students experience theft or burglary’ (Lucy Miller, 2014). As students, we relate to the many worries that students have when applying to university and living independently; safety being one of the most important.

Currently, on the market, motion detection sensors exist. However, within a home/office, a sensor would be required in all the rooms that would be monitored. Instead, our solution consists of a single sensor that is placed on a car that moves between the rooms. This would be much cheaper than purchasing multiple sensors since a high-grade commercial sensor would be more expensive than the car parts themselves.

Literature and technology review

The ring alarm motion detector is a popular commercial product that detects motion and rings an alarm. This popularisation of this and similar products provided evidence for our chosen problem. Detectors such as these are often sold in packages, where multiple sensors and a hub are sold, often costing hundreds. Since we are focusing on reducing the cost of a motion detecting system, our solution should be appealing to homeowners foscuing on cheaper alternatives. Since the sensors are the most expensive part of the system, our final solution should use a technology that is on par or better than the commercial sensors.

Two arduinos (or any independant microconroller boards) are necessary for this project as there is a master control component (to behave as a hub) and a slave (the car) component. The car is designed to move between rooms and requires a way to communicate with the master component. While a long wire would suffice, it would take up unnecessary space. Thus, we used two HC-05 bluetooth modules to establish a wireless connection. Bluetooth has an effective radius of 10 meters, which allows the car to cover most areas of an average house or several rooms in an office. The master arduino sends instructions to the car and the car scans or moves accordingly while relaying information back to the master arduino where needed.

During development, we had the lidar and ultrasonic sensors available - two sensors that are used to measure distances. Whilst the ultrasonic sensor (U.S.) uses ultra high-frequency sound waves, the lidar uses light waves. The lidar sensor is advantageous over the U.S. sensor since light waves travel faster than sound waves. The lidar sensor also has greater accuracy over the U.S. sensor since the light is generally unwavered from ambient light whereas the U.S. sensor works poorly for objects with soft materials (easily absorbs the waves) (Burnett, 2021). However, only a lidar sensor that ranges between 4 - 180cm and a U.S. sensor that ranges between 5 -

400cm was available to us. Since the car should detect changes in a room, the U.S. sensor would be a more suitable choice since 180cm is not nearly far enough. Ideally, a lidar sensor with a greater range would be used.

<u>Development Process</u>

Our original idea was to use three wheels, where the two front wheels are motor-driven and the small back wheel was able to swivel 360°. However, we feared it would struggle on smoother surfaces like carpet and be more prone to stability issues, like tipping over. We chose to use four wheels, but we had two different types of wheels at hand due to limited resources. The wheels with better traction were placed at the back to overcome inertia to allow the smoother smaller wheels at the front to turn. Friction tape was also added to the smaller wheels to give them a rougher surface, increasing the coefficient of static friction between the wheels and the ground and producing a desirable amount of traction.

During development, an issue arose where the master Arduino Uno was running low on memory (70 bytes for local variables) due to the multiple large arrays that were used. We had already minimized the size of the array by defining them with a short int data type and justified the need for multiple arrays - two arrays to store a room's initial map and two arrays that store each scan. A viable solution at the time was to use another Arduino Uno as an extension of memory that could also handle some of the processing to reduce the memory used by the master Arduino Uno. In the future, it would be sensible to use an external storage medium such as an SSD or an Arduino with a larger memory capacity such as the mega (256KB). However, upon review, an array to store a scan was removed, since it was not sensible to average the data between two scans - a change between the two scans would be mitigated. The dynamic memory was reduced enough, but we were nearing the flash memory limit.

Originally, the master Arduino transmitted a signal to the slave with an instruction to scan at an angle number. This resulted in 360 transmissions between the two Bluetooth modules. At first, we had observed each scan taking ~2 minutes and assumed it was due to power limitations. To reduce the size of the master program, changes were made so the master would simply send a scan instruction and the slave would handle the iterating through 180°. A string of distances would then be sent to the master where units of distances were deliminated with ',' and the end of data would be terminated with ">". This resulted in 2 transmissions between the components, in turn reducing scan time to ~10 seconds. A quicker scan time would be beneficial since it mitigates the chances of a change occurring before the final scan at a position, which would delay the time taken for the change to be notices.

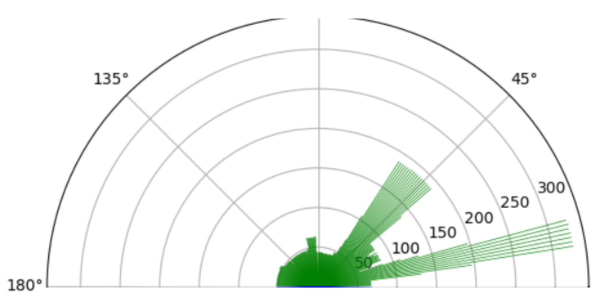
We also considered a two-wheel drive but concluded that to operate on different surfaces (carpet, tiled, laminated), a four-wheel drive was ideal. A motor shield was used to control the motors as the Arduino didn't direct enough current towards the motors thus requiring transistors, diodes, an h-bridge, and an external power supply to control the speed and direction of the motors. With the motor shield, only an external power supply was needed as it already contained an h-bridge to reverse the polarity and two drivers to direct the necessary current to power the motors.

Prototype Implementation
The car follows a designated route set by the user on the master Arduino, stopping and scanning its surroundings at the ends of the route. The car traverses the route and performs an initial scan upon reaching either end, rotating 180 degrees and reading distances from the car to the surfaces of objects in the room by using an ultrasonic sensor to send and receive sound waves. The car will continue to traverse the route and perform several scans (determined by the rotation of the potentiometer on the master) and compare the values to the room's initial scan. If there is a significant difference in a section of a room then an RGB LED flashes red and blue, and the piezo will play a sound.

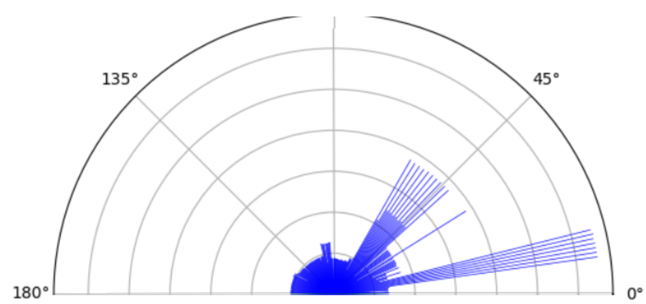
The user will be able to control the number of scans that the car takes at each point via a potentiometer on the master and the LCD screen will display to the user, which point the car is traveling to, when the car is scanning, alert the user when a change has been detected, and the number of scans that will be performed. The LCD screen is essential because the user can place the master arduino in a central position between the rooms and monitor where the car is and what is happening - allowing the user to interact with the product would lead to better satisfaction.

The car uses a driver motor shield to direct an appropriate amount of voltage for a specified time to its respective motors. The car is capable of moving forwards, backward, and spinning left or right on the spot. The instructions to move are received from the master arduino.

The ultrasonic sensor is attached to a servo, allowing it to rotate up to 180 degrees. The distance at each angle is measured by multiplying the time between echo and trigger signals and the speed of sound. Due to the behavior of sound waves, anomalies were commonly found where sound waves were reflected in random directions or absorbed by an object. For the prototype, anomalies were removed if each value was more/less than double/half the mean of neighboring values. This simple algorithm proved to work quite effectively:



Before



After

To determine a change in the environment a paired t-test was used on the data from the scan and the initial map data. However, a paired t-test between the entire data set did not work. This was because if points 0-170 remained the same and points 170-180 differed by a significant amount (>30%), the change across the entire dataset would be insignificant since most of the data did not change. Wilcoxon signed-rank test could be used, however, it is simply far too complicated and unnecessary. Instead, the dataset was clustered into 10 equal-sized clusters with a paired t-test performed between each cluster. Even if the data within the cluster varied by a large amount, the mean of equal clusters in each data set would be evidently the same, hence the trend of data within the cluster would not matter. The degrees of freedom eis then 17 since a t-test is applied on each cluster. This changes our critical value for a 5% significance at 17 d.o.f to 2.110. A 5% significance level was suitable since the smallest detectable change at this significance in the environment was what we wanted (a reasonable change).

Conclusion

While the final prototype provided a simple solution to the problem of expensive cameras for security, it was not optimal and could be improved in many aspects. In the next generation of our solution, silent motors would be applied to reduce the chances of a burglar avoiding the sensor. Lidar or infrared sensors with an amplified effective range would also be applied due to their increased accuracy. Tilt sensors would be implemented to account for burglars disabling the car. Humidity and temperature sensors would be added to adjust calculations for the ultrasonic scanner as they affect the speed of sound. Wifi would replace Bluetooth in terms of communication as it allows for a larger effective range and greater speeds of data transmission.

Overall, the car fulfills the original success criteria, which is to make homes more secure and allow owners to feel safe. Having a moving security system aids in bringing comfort as it is always active and alert. It’s effective and inexpensive design makes it a great security system for any homeowner, as no one should have to feel unsafe in their own home.

Works Cited

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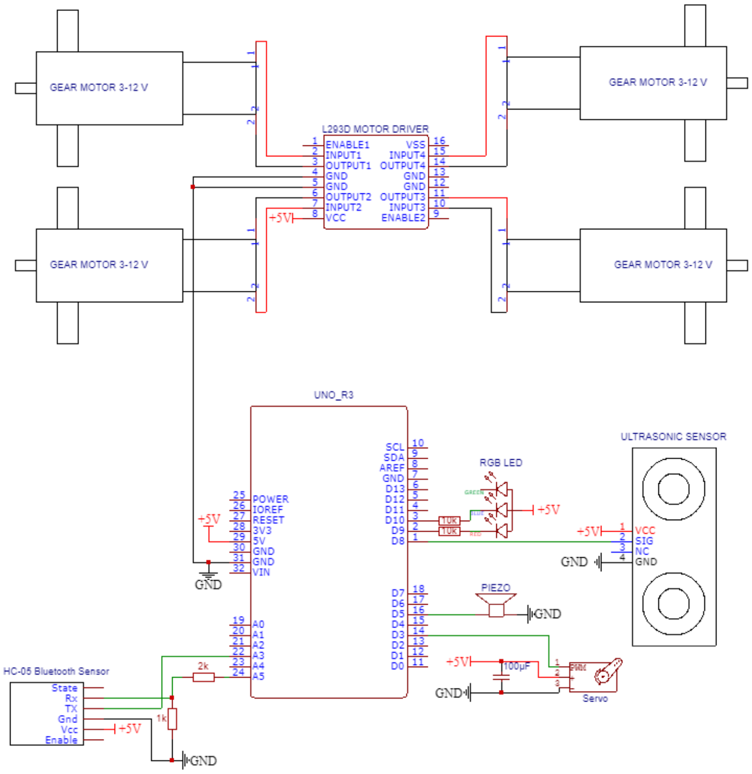
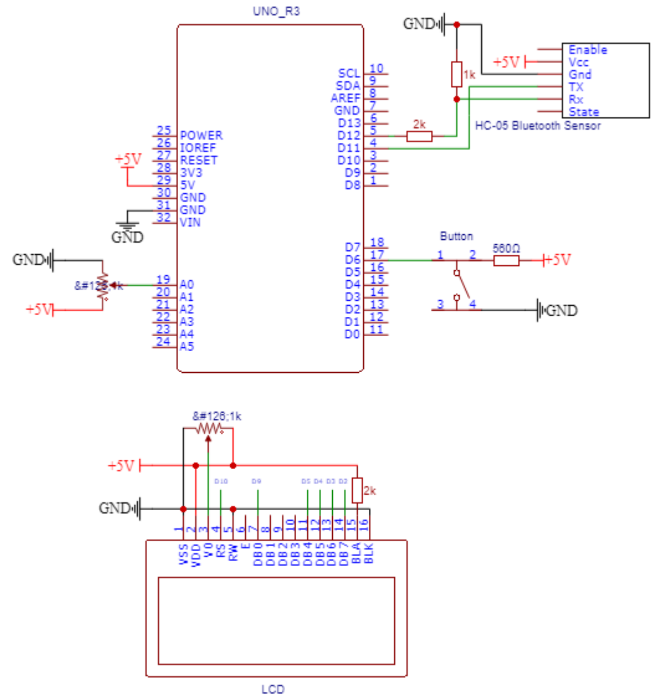
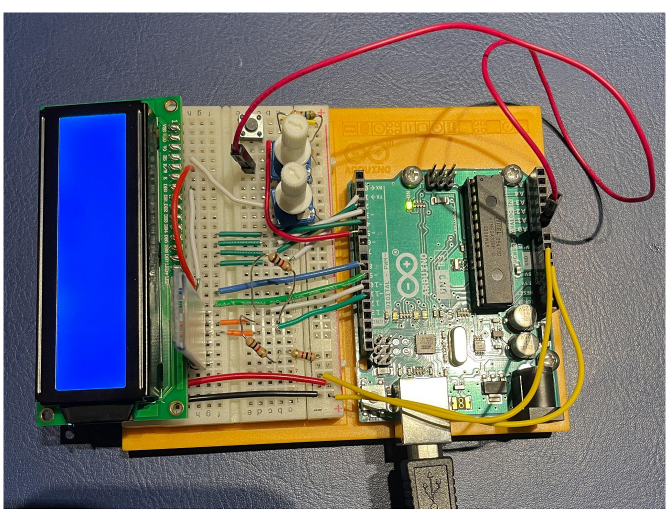
Appendix





Remote Device



RC Car with Scanner