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ENGINEERING PROTOTYPE

–for–

a Home Surveillance System

WENTWORTH INSTITUTE OF TECHNOLOGY
ELEC 4500: SENIOR ELECTRONIC DESIGN I

Instructor: Professor Grenquist
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Abstract

A technical proof of concept for a lightweight, customizable, and scalable home surveillance system is presented in this documentation. This phase primarily of evaluating several object detection methods–in day and low ambient lighting conditions–for humans and vehicles.

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1 Introduction

The Home Surveillance System is divided into two subsystems: a Raspberry Pi 2 with a camera module that performs computer vision and a night vision circuit comprised of an ambient light sensor and an array of IR LEDs. These two subsystems operate separately, allowing the user to be selective in their home monitoring configuration.

The Home Surveillance System–at its current iteration–is capable of detecting human through their frontal and side facial features. Motion detection runs continuously and acts as the idling state. Once motion is detected in the frame, the system isolates the sections. Finally, it seeks out human faces in the bounded through Haar-like features–a process pioneered by Viola-Jones [1].

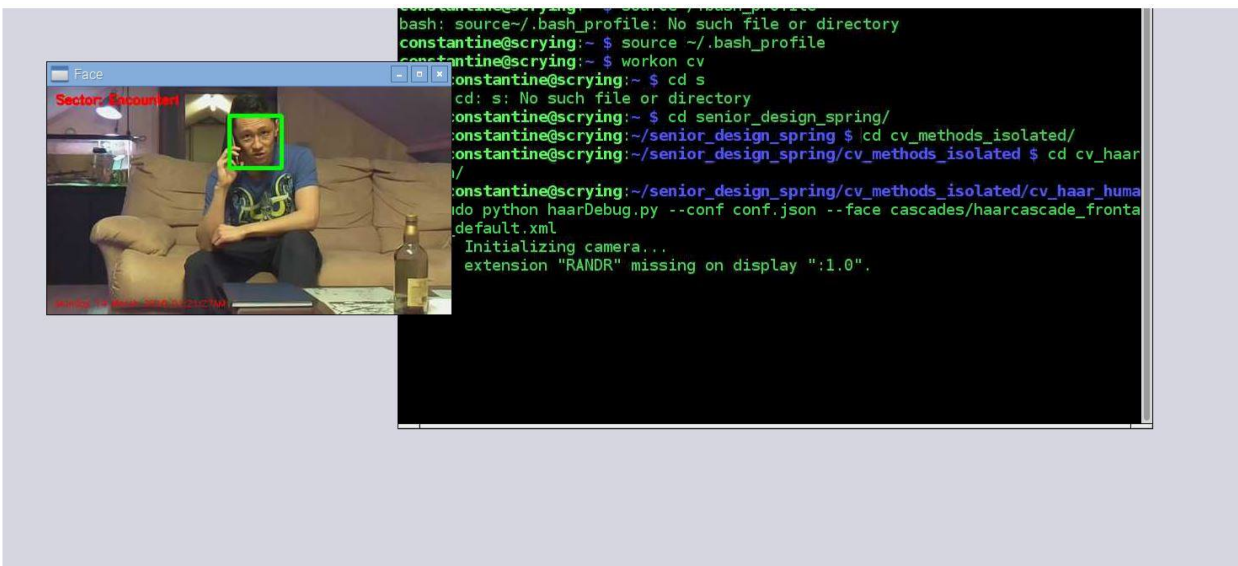


Figure 1: Remote access to the livestream through VNC.

The user is able to view a livestream of the camera through an encrypted VNC connection, allowing for secure access within or without the home network. Figure 1, shows a screen shot of the proof of concept's livestream. This was taken from A. Martinez's laptop, which was connected to the RPi2 from an outside network.

2 Prototype Specifications and Credentials

Table 1: Software utilized within prototype.

Technology	Version	Type	License
Raspbian	Jessie	Raspberry Pi Linux OS Distro	GPL v2
Python	2.7	General Purpose Language	Python Software Foundation
OpenCV	3.0.0	Computer Vision Library	BSD
TightVNC	1.3.9-6.5	Virtual Computing Network	GPL v2
Weaved	1.3-02	Network Managing Platform	GPL v2

Table 2: Credentials to the prototype system.

Name	Type
scrying	RPi2 Hostname
constantine	RPi2 Username
cv	Virtual Environment

3 Night Vision

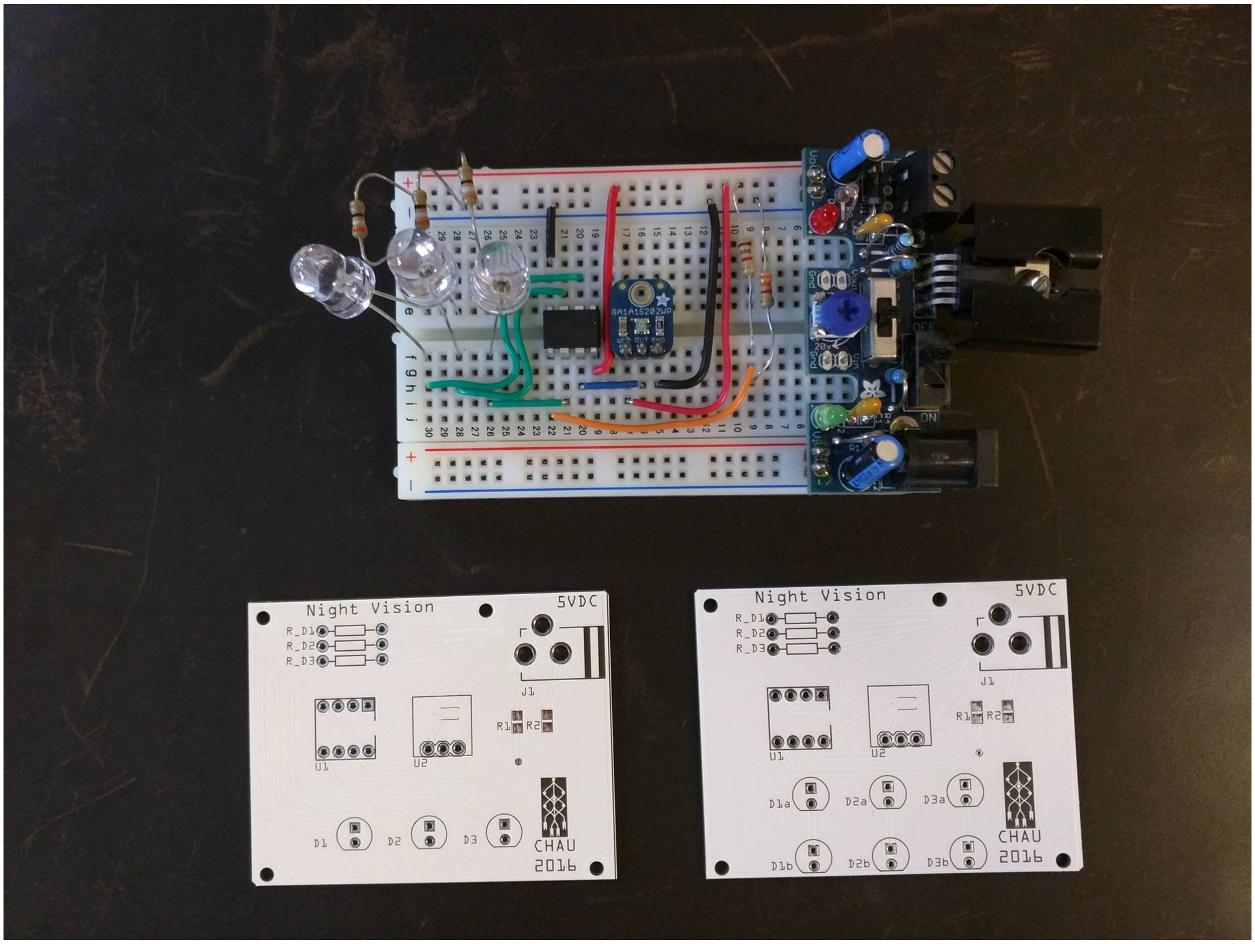


Figure 2: Night Vision subsystem printed circuit boards.

Figure 2 shows the two custom PCBs for the IR LED arrays. These boards are completely separate from the main Computer Vision subsystem. This allows the user to position the Night Vision boards at locations of interest. For example, the user could position the Computer Vision subsystem above their front door and position one or more Night Vision subsystems near their vehicle or walkway. The flexibility of the Night Vision subsystem allows for greater customization to the end user, who can decide to either on-board, off-board, or not utilize the boards based on their needs.

4 Facial Detection

Haar Cascade Classifiers is the method chosen to detect human faces.

4.1 Indoors Facial Detection: Environment

The indoor evaluation environment was a 12x20 ft room. The room was lit with two overhead, bare T5 fluorescent bulbs in parallel, outputting approximately 3500K neutral white. The primary evaluation distance was 4 ft, however, 8 ft and 10 ft were also evaluated for scale invariance.

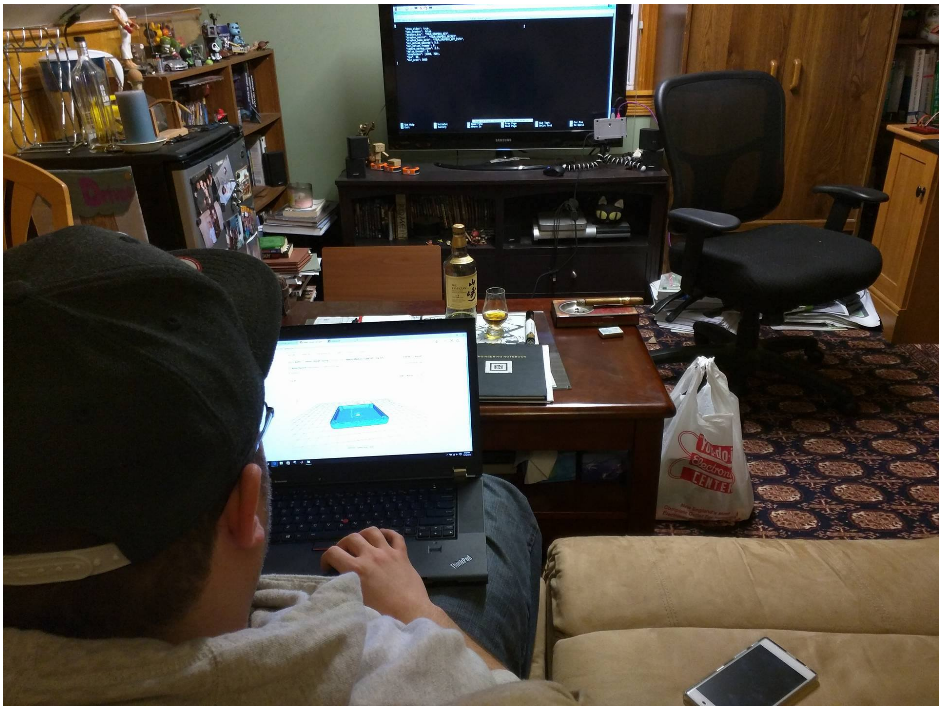
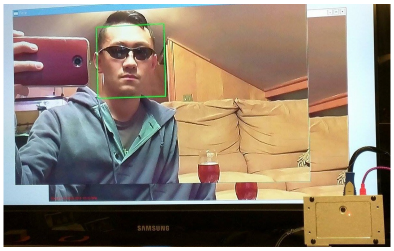
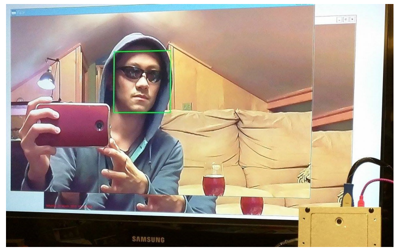


Figure 3: Indoor evaluation environment. The prototype is on the right edge of the TV stand. The white plastic bag is approximately 4 ft from it, and Nelson's position is approximately 8 ft away.

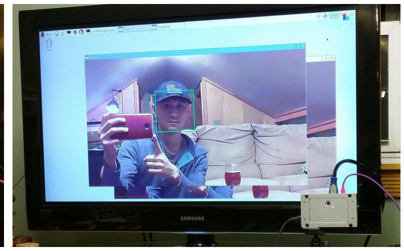
4.2 Indoors Facial Detection: Head Wear



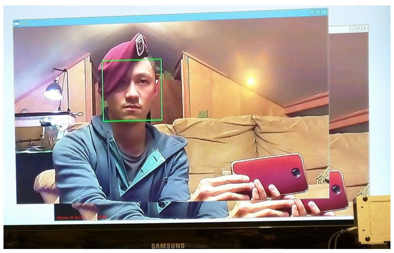
(a) Sunglasses.



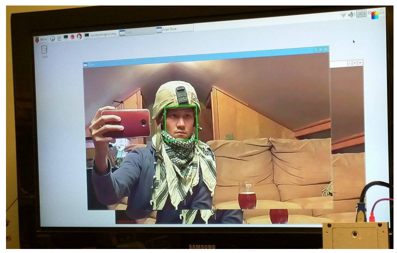
(b) Hoodie and sunglasses.



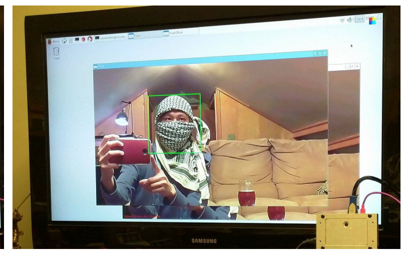
(c) Baseball cap.



(d) Paratrooper beret.



(e) Advanced Combat Helmet.



(f) Shemagh.

Figure 4: Indoor facial detection evaluated through various head wear at approximately 3-4 ft distance.

4.3 Indoors Facial Detection: Distance

Figure 5 demonstrates that the system is able to detect human faces at 3 ft., 8 ft., and 10 ft. The dog in the frame was disregarded as this specific evaluation only searched for human faces.

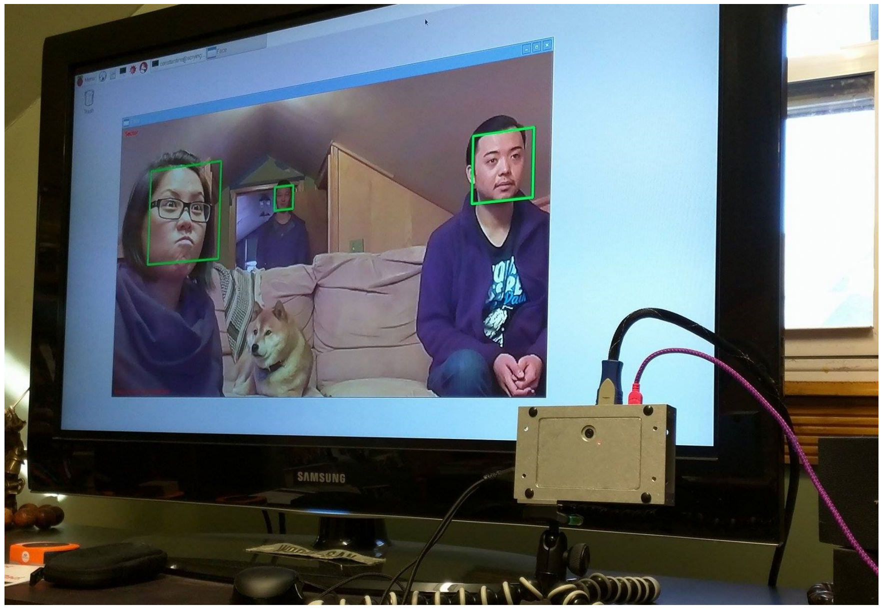


Figure 5: Positive detection for three humans at different distances.

4.4 Nighttime Facial Detection

Low-ambient lighting conditions proved to be a formidable and admittedly underestimated challenge. The success rate for human facial detection remains low, hovering around 20% with the 3-IR LED Night Vision board activated. The chance for a positive detection increases when the distance from the Night Vision board decreases. At approximately 3 ft., the success rate increases to approximately 40%.

Plans to increase success rate includes:

1. Modifying the intensity of the IR LEDs.
2. Increasing the numbers of IR LEDs to the Night Vision board.
3. Increasing the numbers of Night Vision boards.

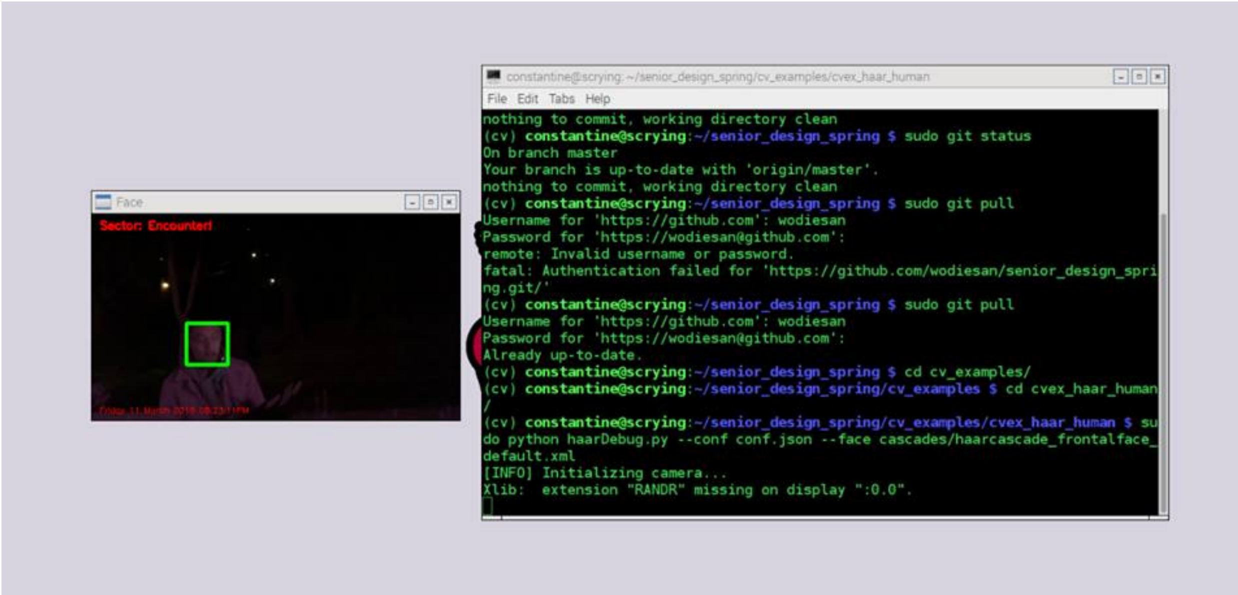
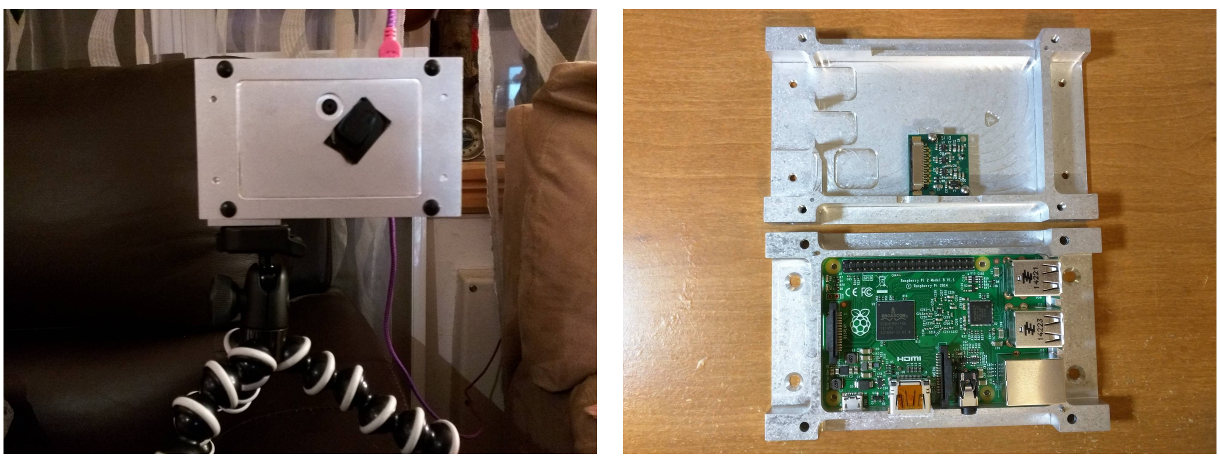


Figure 6: Positive facial detection at night, IR LEDs active.

5 Enclosures

During the Proposal Phase the design included a MobileApp Systems Proto Armour Enclosure for the RPi2. During cost analysis, it was quickly concluded that–while beneficial at the proof of concept stage–this component would not meet the requirements for a production-level product. The choice of the Proto Armour was based on the enclosure's robust aircraft-grade aluminum, support for the camera module, and numerous mounting holes at each side of the case. The Proto Armour, however, wasn't designed to be weatherproof. In addition, the cost per enclosure at $45 per enclosure represents close to 30% of the direct materials cost per unit. This high cost disqualified the Proto Armour Enclosure for purposes beyond proof of concept designs.



(a) External view.

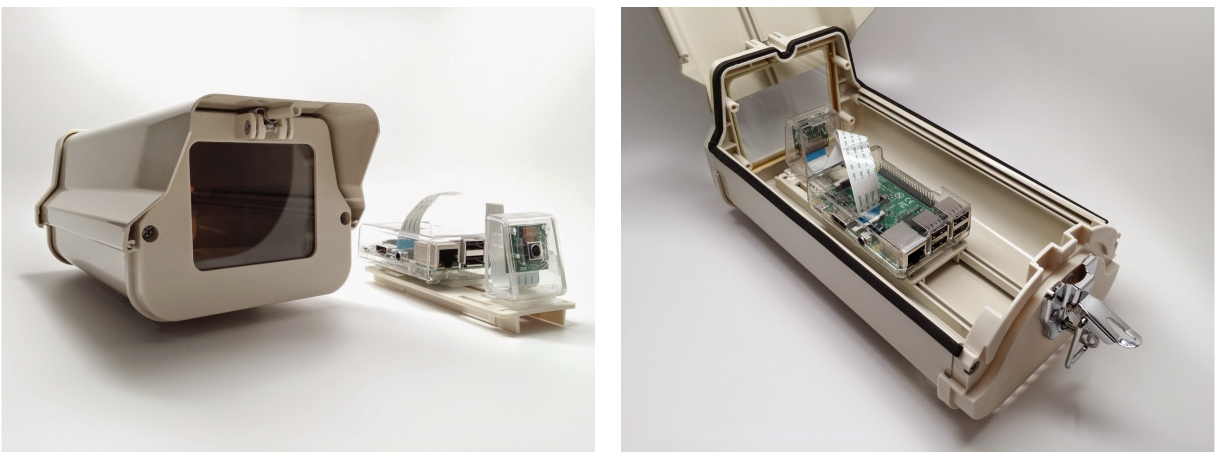
(b) Internal view.

Figure 7: Proto Armour Enclosure by MobileApp Systems.

5.1 CCTV Weatherproof Enclosure

A strong contender was a generic 15 in. length CCTV Weatherproof Enclosure. This enclosure is primarily aluminum is sealed with heavy duty rubber to prevent water intake. Priced around $25, this enclosure is an improvement from the Proto Armour. This candidate, however, was rejected for several reasons:

1. Enclosure is larger and heavier than necessary for the system, making inconspicuous installation unlikely.
2. The large viewing window and the distance where the camera is mounted increases light pollution from the surrounding environment as well as the RPi2 diagnostic LEDs.
3. LEDs inside: The viewing window isn't wide enough for both the camera module and Night Vision board.
4. LEDs outside: A secondary enclosure will be required to custom mount onto the CCTV enclosure.
5. While not required, additional enclosures for the RPi2 and the camera module would be recommended, thereby increasing the cost to the level of the Proto Armour Enclosure.



(a) External view. (b) Internal view.

Figure 8: Example CCTV enclosure re-purposed for a RPi2-based security system. Haldas, Mike. Raspberry Pi Outdoor Camera Housing.

5.2 Main System Enclosure

After careful consideration, a unanimous decision to design custom weatherproof enclosures was made based on several reasons:

1. A custom design would keep expenditure for enclosures within reasonable bounds.

2. The enclosure can be designed so that the gap will be minimal between the camera lens and the enclosure's protective glass cover.
3. Separate enclosures can be designed: One for the RPi2 and one for the Night Vision board, allowing for modularity through various configurations (for example: two Night Vision Boards).

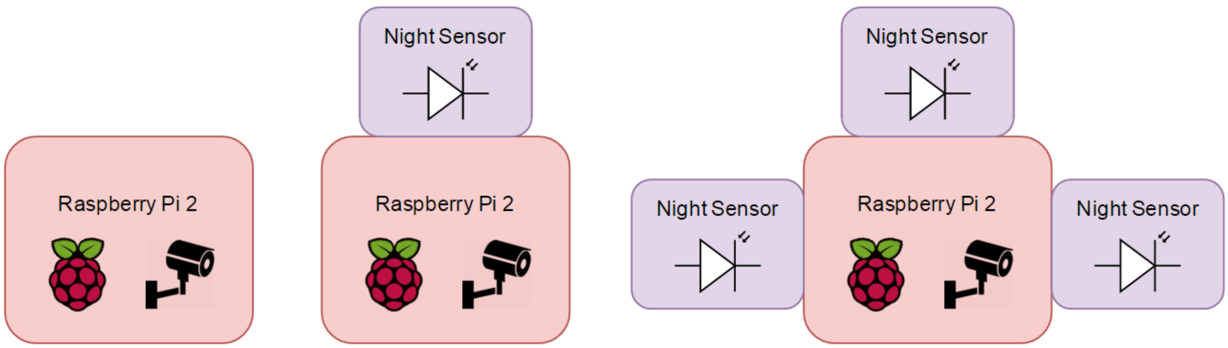


Figure 9: Various attachment configurations.

The enclosures can be 3D printed for quick evaluation. The only possible issue with this method is sourcing the necessary o-rings and screws, but this won't likely be a real concern. Custom designing an enclosure for the Night Vision board improves the functionality of the Home Surveillance System during times low-ambient lighting. By focusing on modularity as a feature, each Nigh Vision enclosure will be able to mount on the top, left, and right sides of the RPi2 enclosure.

6 Challenges and Considerations

6.1 Power and USB Current Draw

It is recommended to power the system with a 5V, 2A microUSB cable power supply. Using a power supply with lower current capabilities will result in instability.

6.1.1 USB Hub

In addition to the 2A power supply consideration, end users that plan on attaching unrelated USB devices could potentially experience intermittent wifi connection, amongst other issues. Current draw from various USB devices was examined through the `usb-devices` and `lsusb -v` commands in Raspbian:

Table 3: Example average current draw of the Home Surveillance System with unrelated USB devices attached to the RPi2 unit.

Device	Current Draw
Raspberry Pi	750mA
Camera Module	100mA–260mA
Wifi Dongle	50mA–100mA
Keyboard and Mouse Combo	98mA
External Hard Drive	750mA

While it might seem okay to run the RPi2 off of a 5V, 2A power supply, this might not be the case depending on additional USB devices unrelated to the home surveillance system. For example, a user could attach some or all of the USB devices listed in Table 3. The result is an average 1.96A current draw. Without a powered hub, this setup would risk wifi stability when the user leverages the VNC server. A powered USB hub isn't necessary at the current design iteration, however, it is advised to consider one if there are plans to run other USB-based, current-hungry devices on the RPi2 unit.

6.1.2 USB Current Limiter

The RPi2 includes a current limiter for USB peripherals to reduce brown-outs on the main supply. The total current drawn by USB devices defaults to 600mA, but this can be increased to 1.2A, doubling the default allowance. The RPi2 proof of concept unit `scrying` has been adjusted for this increase. This adjustment is found in `/boot/config.txt`:

```
max_usb_current=1
```

Increasing this current limit seems to result in a more stable wireless connection for remote viewing through VNC. If power-related issues occur (as indicated by the flickering red power LED on the RPi2), commenting the line out of the file should be the first step in debugging the issue.

6.2 Security

The current design relies on VNC to access the RPi2 desktop remotely. The initial process to VNC from an outside network required port forwarding to a specific TCP port. This method presents a security vulnerability; by default, the transmitted data isn't encrypted. This becomes a concern when accessing the system outside of the home network.

Weaved, a cloud-based network platform, was chosen as a safeguard for secure access through VNC and HTTP [2].

7 Project Development

7.1 Anticipated Feature: Android App

An Android app to view the livestream would greatly increase the accessibility of the Home Surveillance System. This feature was tentatively announced during the Proposal Phase, but time constraints limited the resources available for Android development. As a result, the Android app is currently on hold until the next major iteration of the system.

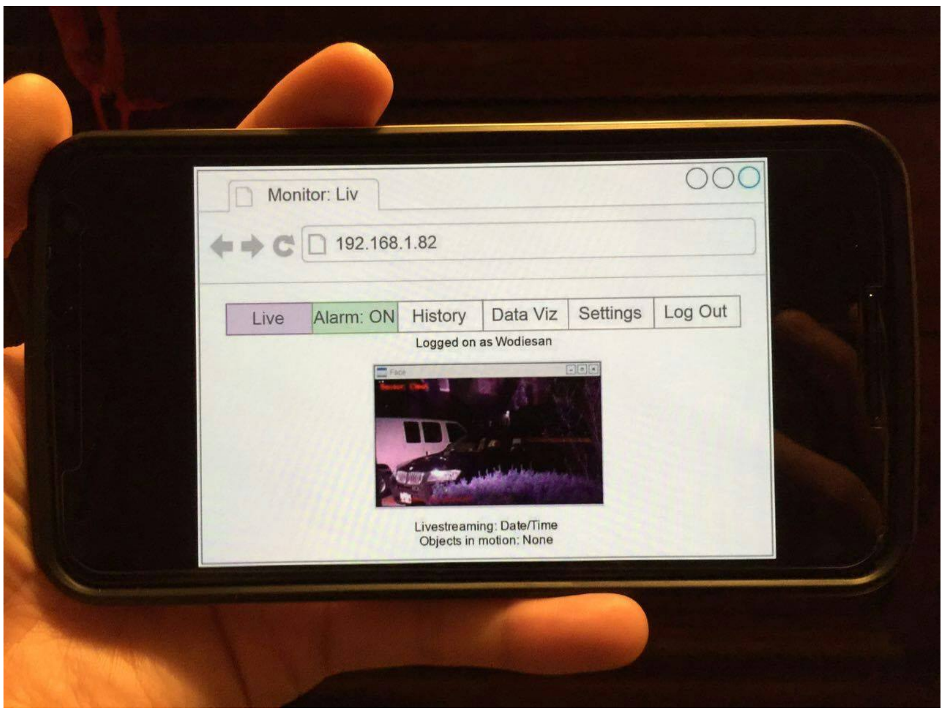


Figure 10: Concept UI for the Android app.

7.2 Anticipated Feature: Servos

User-controlled pan-tilt movements is a planned feature for the next major iteration of the Home Surveillance System. The tentative plan is to allow users to control the system through the website livestream as well as through the planned Android app.

References

[1] P. Viola, M. Jones, "Robust Real-Time Face Detection," in *Int. Jour. Computer Vision*, vol. 57.2, pp. 137-154, 2004.

[2] "Raspberry Pi - Weaved Inc", *Weaved Inc.*, 2016. [Online]. Available: http://www.weaved.com/raspberry-pi-remote-connection/. [Accessed: 14MAR2016].