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ENGINEERING PROPOSAL

–for–

a Home Surveillance System

WENTWORTH INSTITUTE OF TECHNOLOGY
ELEC 4500: SENIOR ELECTRONIC DESIGN I

INSTRUCTOR: PROFESSOR GRENQUIST
SPRING 2016

Table 1: Revision history.

Senior Electronic Design Proposal		Document Number: ELEC4500–2016	
Rev.	Description of Change	§ Affected	Originator
01	Initial Release	All	N. Bamford, R. Chau, A. Martinez
02	General Proofreading Add Glossary and Calculations Add Fig. 6–9 Revise Fig. 5, Sec. 6 & References	All	R. Chau

Abstract

A low-cost, low-maintenance, Raspberry Raspberry Pi 2-based home surveillance system is proposed in this document. This system is designed to allow a homeowner to record digital footage–through low-ambient environments–when a motion threshold is surpassed. The system will include basic human detection and object recognition features, and the recorded instance cataloged by the object that activated the camera, e.g. human, vehicle, and others. This proposed functionality will allow a homeowner to quickly access the database of footage through categorical “bookmarks” based on metadata such as date, time, and type of object.

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1 Problem Statement and Motivation

Newton, Massachusetts is constantly rated as one of the safest cities in the country; that doesn't mean that crime doesn't occur in the city [1]. At a localized point of view, one of the engineers on this project–a resident of Newton–accumulated numerous experiences that required the actions of Newton Police Department. In 2015, the neighbor of this engineer had their house broken into. Thieves kicked in the back door; no one noticed the incident. A few months later, Newton Police was called upon to dust (for fingerprints) a family members work van after it was broken into for tools. On the week of Christmas, the garage of another neighbor was broken into overnight. This neighbor was restoring a classic muscle car, and the progress was halted due to stolen rare parts. The worst incident, however, happened a few years ago to the engineers friend that was–at the time–living in West Newton. It was a home invasion where the homeowner was tied up at gunpoint, and the thieves tossed her dog into a closet before leaving with jewelry and a safe. To this day the perpetrators were never caught.

The constraints of this device, as determined by informal surveying of Newton homeowners, include the ability to determine if there is an object in motion near a home entrance and to capture a video if this criteria is met. A secondary requirement requested asks for the design of a method to distinguish a human from other objects such as vehicles, and to create a metadata sorting method based on these identification criteria alongside date/time.

The design must take these traits into consideration, or else the system would be severely handicapped and similar to existing commercial systems. The proposed home surveillance system acts as an affordable, mobile, and open source bridge between available, albeit expensive commercial products that either secures empty homes or monitor internal dwellings.

2 Background

Literary research for this design split into two distinct avenues: Computer vision and a novelty investigation into currently available commercial solutions.

2.1 Computer Vision

The development of an image processing technique that fits our objectives involves object recognition within the field of computer vision. Computer vision is the science of imagery acquisition and interpretation through the use of computers [2, p. 1-5]. Object recognition describes the task of locating, or recognizing, specific objects within images. In the case of our design, object recognition tasks could be incorporated to evaluate initial images arriving from a camera unit for identification of humans or vehicles. The object recognition methods that are currently being considered includes Haar-like features and blob detection.

2.1.1 Haar-like Features

Haar-like features gets their namesake due to similarities to Haar wavelet transforms. It is an object recognition algorithm that seeks out common patterns by calculating spatial relationships of information (such as contrast) of the target object [3, p. 1]. These patterns that the Haar-like algorithm checks are rectangular features that specific objects all have, such as the distance between a humans eyes, or nose. As human recognition is an important feature in the proposed system, a Haar-based facial detection algorithm will be investigated for the prototype.

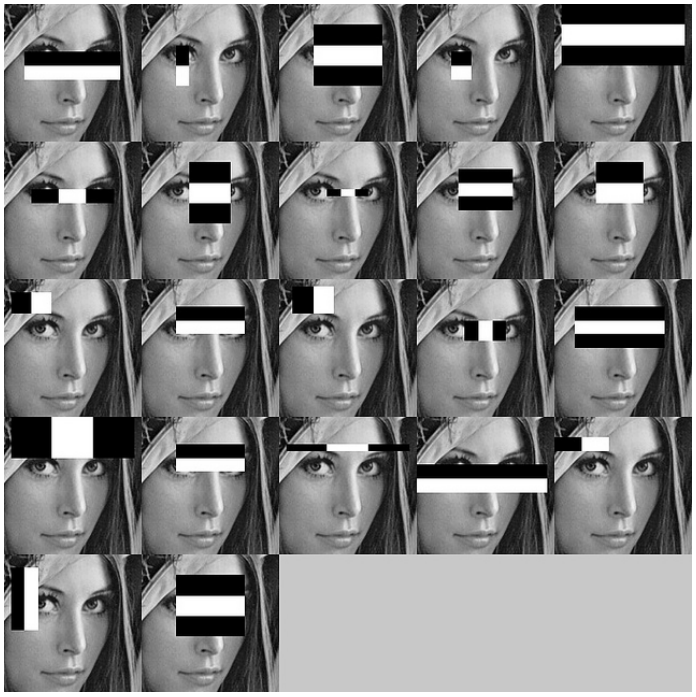

Figure 1: Haar-like cascade algorithm used to detect human faces.

2.1.2 Blob Detection and Analysis

Blobs refer to regions of similar pixels in an image. Blob algorithms locates these regions and assigns a category to it based on light or color values [4, p. 8-18]. This method requires segmentation of the target image, which involves in the removal of everything outside the region of interest. Depending on the target environment, blob analysis is subject to noise in the form of mis-categorized blobs. The deployment of a blob analysis algorithm would require significant pre-processing of our target object. The advantage of utilizing blob detection, however, includes simple identification of large, single-color dominant objects such as vehicles. Due to this capability, blob detection will be one of the algorithms used for the prototype. Of concern is the dependability of blob detection during low ambient conditions.

2.2 Novelty Investigation

The investigation focused on three major companies with home monitoring commercial solutions. Verizon and Comcast have indoor and outdoor cameras that provide a wireless security system capable with live stream alongside phone apps. This is something that the team aims to pursue (time-dependent). For the proposed system, it is important that the final design remains cost efficient, and the main feature to implement–object detection alongside an alert system–is something that current commercial products haven't introduced to the market. Looking at companies that supply commercial home surveillance systems, the team wanted to identify:

- Patterns of features.
- Whether the plan comes with a subscription.
- Installation cost, if any.
- Cost of the physical equipment.

2.2.1 Verizon

Verizon offers a home security camera using the brand Canary, a 1080p HD camera able to live stream real time video and audio via a laptop or an app (requires 1 Mbps upload) [5]. The camera is equipped with automatic night vision able to viewable with a 25 feet range. The camera is capable of motion detection which can be activated and start recording once it senses movement. The sensors are a 3-axis accelerometer with ambient light and capacitive touch. Verizon does not require a personal installation contractor, the camera is an easy 1-2-3 set up and doesn't require a subscription fee. The app is compatible with IPhone running iOS 7 and higher, and Android 4.0. Cost for everything is $200 which includes camera, microusb cable, guide, and setup cable.

Figure 2: Verizon Canary system.

2.2.2 Comcast

Comcast Xfinity Homes offers a home security camera that seems to be smaller in size but is able to be placed outside of your house since it is more weather-proof [6]. The camera's features are 720p HD resolution, it has night vision although not specified of the range, supports wifi and has sensor motion as well. Although the features for the camera are vague, it comes with a custom tablet and a keypad where you can control the camera. It is optional to use an app on your phone or a laptop to view live video monitoring in and outside your home. For the pricing, the equipment will cost $200 not including the $99 installation fee (depending on where you live). Then there is the subscription fee of $30 a month, which makes the total cost in a range between $300 to $400.

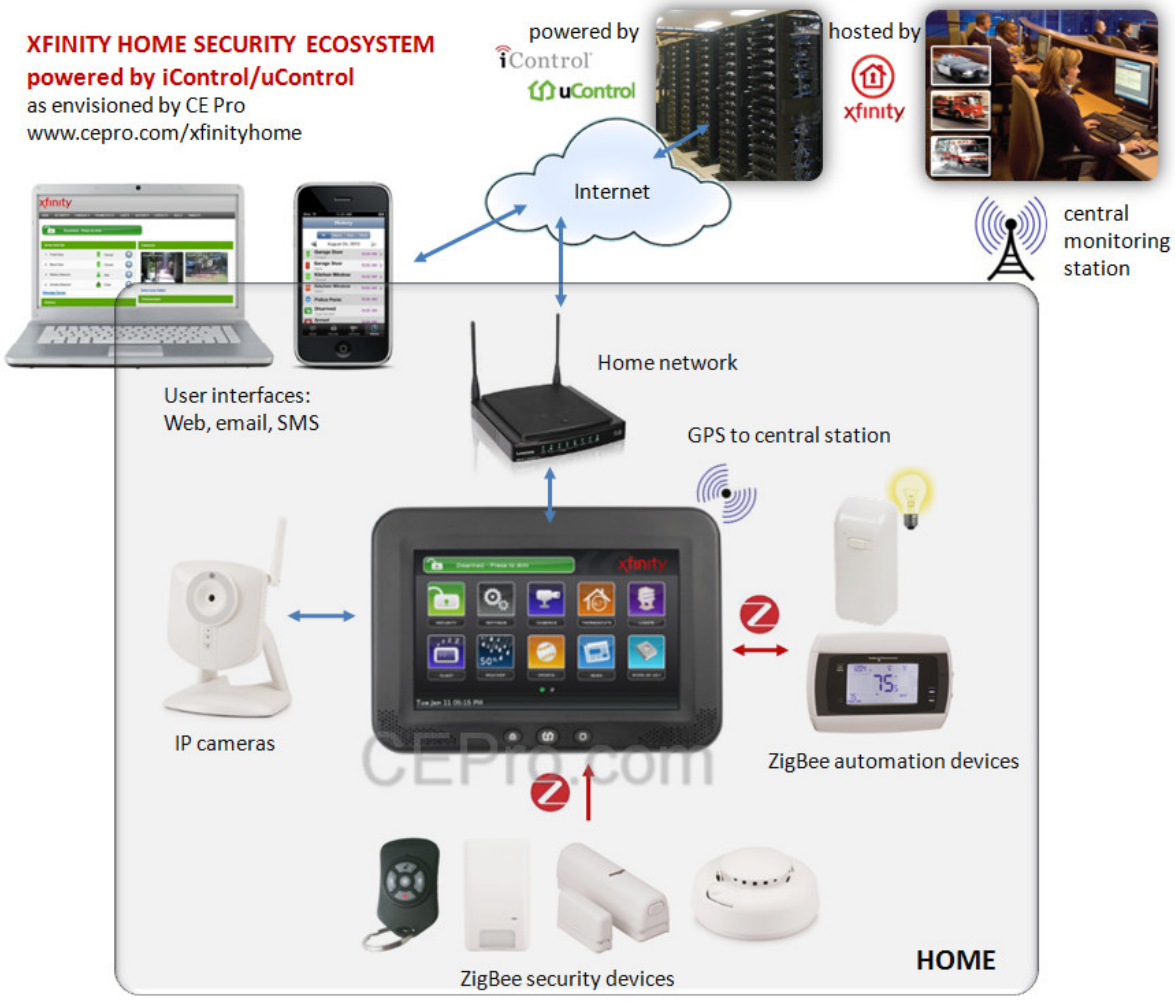

Figure 3: Comcast Xfinity Homes system.

2.2.3 ADT

ADT Security offers a home surveillance camera called the ADT Pulse Camera, it's a wireless day/night camera [7]. The camera is equipped with video motion detection, a light sensor for night vision, and the camera can capture images that can be viewed online. The security system use their own encrypted wifi accessed through WPA2. The downfall of this camera is you are not able to deliver or store audio when recording the device. The device is also capable of high/low temperature monitoring, light control, climate control, small appliance management and remote access. When it comes to the pricing the installation

charge is $99, comes with a 3 year monitoring agreement that is $36.99 per month, which is an added total of $1,331.64.

Figure 4: ADT Pulse system.

3 Proposed Solution

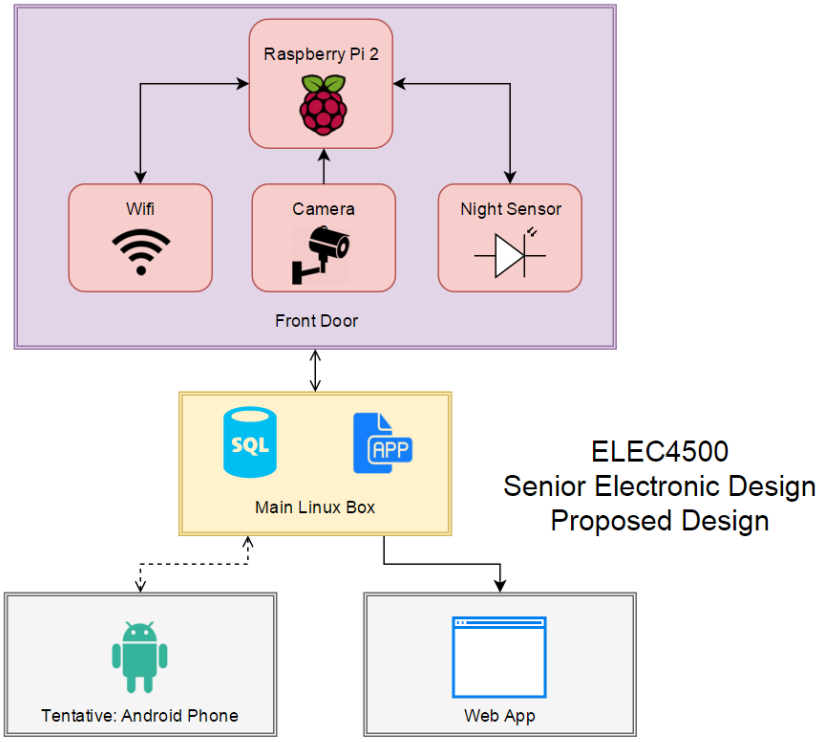

Figure 5: High level block diagram of proposed monitoring system.

3.1 Website Mockups

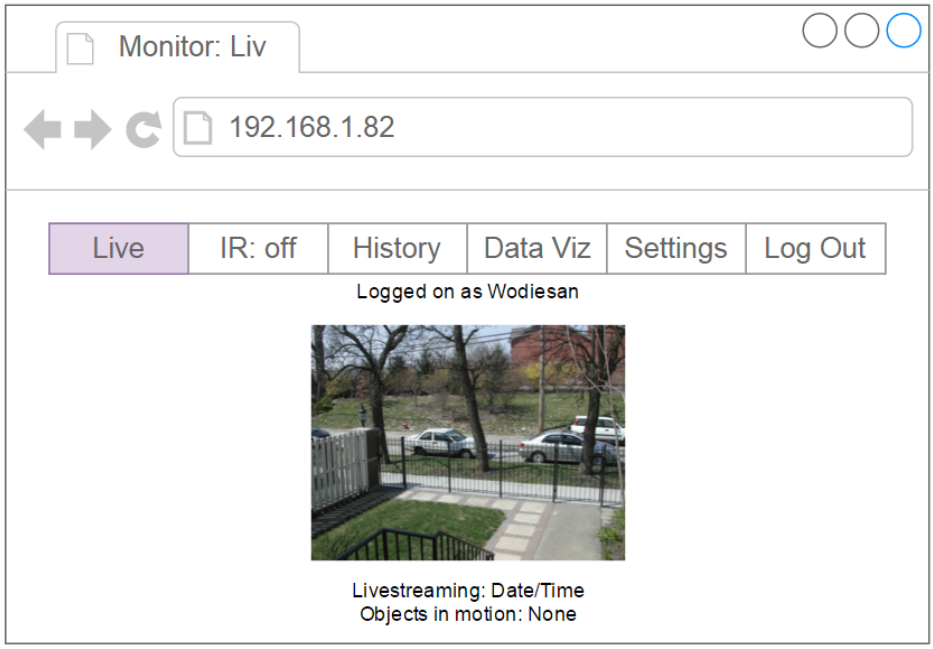

Figure 6: Website mockup: livestream, daytime.

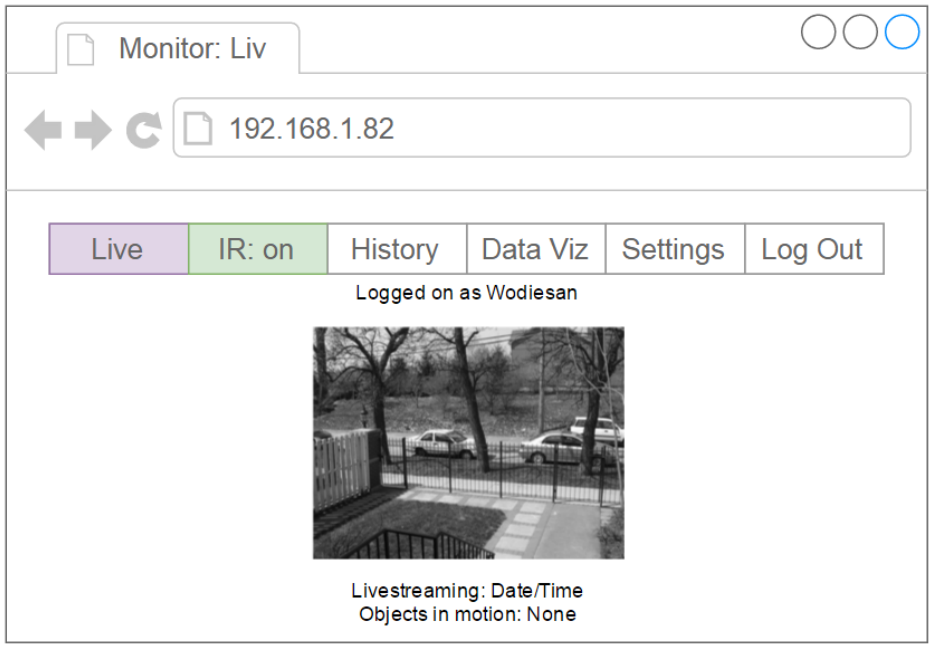

Figure 7: Website mockup: livestream, nighttime.

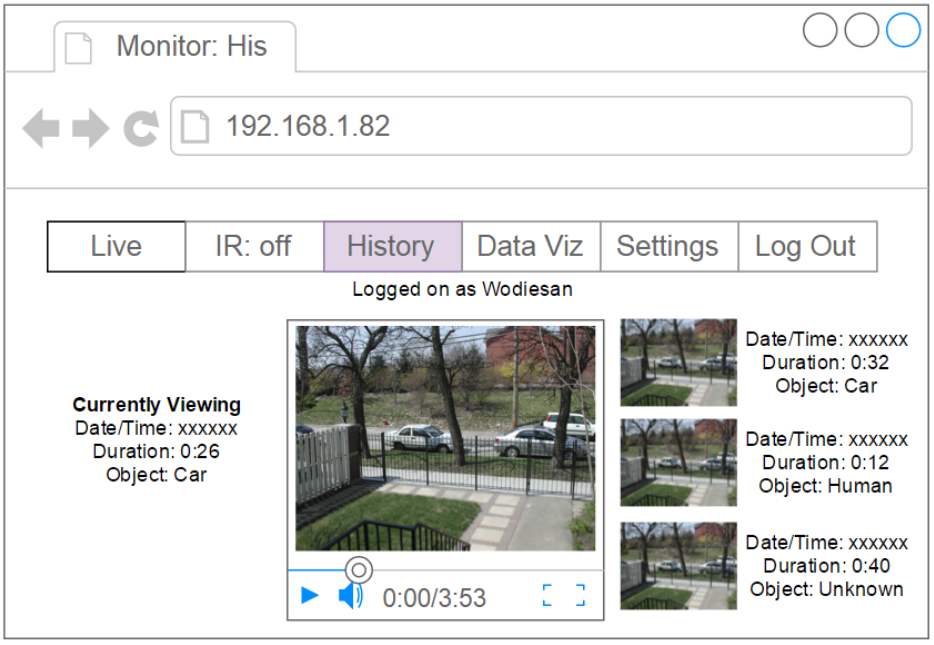

Figure 8: Website mockup: History of detected objects.

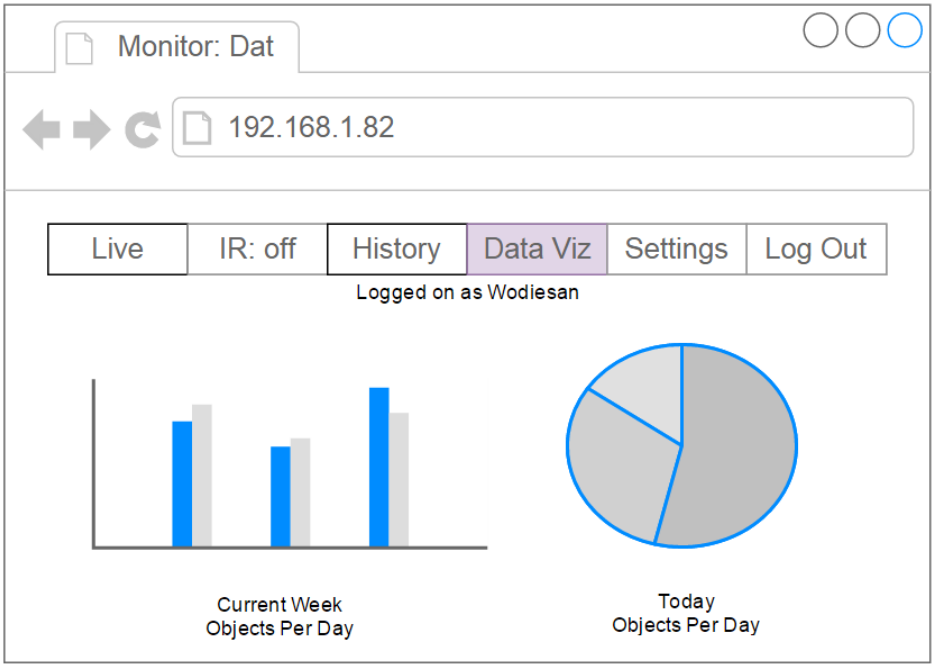

Figure 9: Website mockup: Data visualization.

3.2 Technology Selection and Rationale

In the spirit of universal access to the general public, the proposed system focuses on the utilization of open source hardware and software. As such, the Raspberry Raspberry Pi 2 Model B–a single-board computer–was chosen as the platform for the proposed system. The software architecture will primarily focus on the SimpleCV framework. Simple Computer Vision, officially SimpleCV, is a collection of libraries and algorithms written in Python used for computer vision applications [8]. This open source framework allows the Pi to access an attached camera unit and apply object recognition tasks to the extracted images. The combination of SimpleCV and the Pi means that Python, the official language for both entities, will be the programming language of choice for the overall system.

Figure 10: Raspberry Pi 2 Model B (top) encased with a camera module.

Table 2: Raspberry Pi 2 specifications.

	NEW! Raspberry Pi 2	Model B+
Processor Chipset	Broadcom BCM2836 ARMv7 Quad Core Processor powered Single Board Computer running at 900 MHz	Broadcom BCM2835 ARMv6 SoC full HD multimedia applications processor
RAM	1GB SDRAM @ 450 MHz	512 MB SDRAM @ 400 MHz
Storage	MicroSD	MicroSD
USB 2.0	4x USB Ports	4x USB Ports
Power Draw / voltage	1.8A @ 5V	1.8A @ 5V
GPIO	40 pin	40 pin
Ethernet Port	Yes	Yes

The web platform will utilize a basic LAMP architecture on a separate Linux box for prototyping purposes.

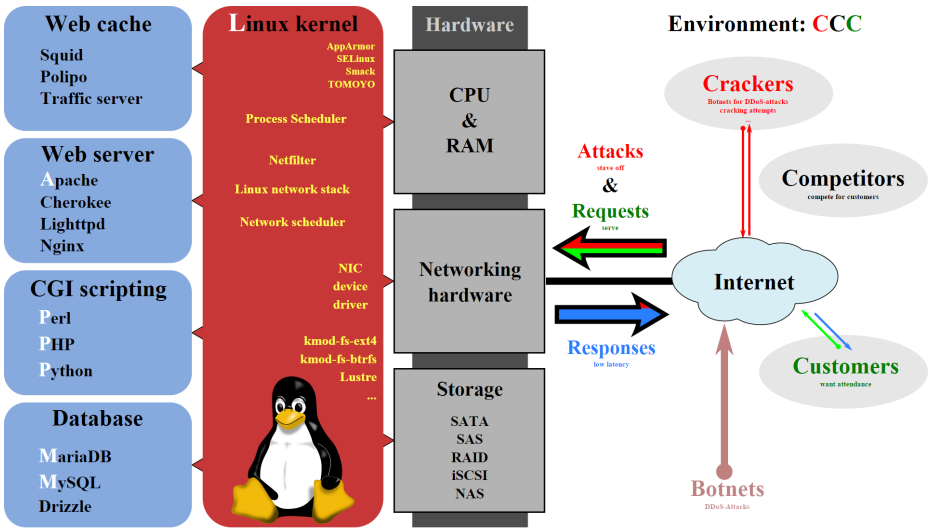

Figure 11: LAMP architecture for web application.

3.3 Feature Comparison of Commercial Systems

Table 3: Comparison of major features from commercial systems.

Feature	ADT	Comcast	Verizon
Weatherproof Camera		x	
Nightvision	x	x	x
HD Quality		x	x
Motion Detection	x	x	x
Livestream	x	x	x
Custom Notifications	x		
Subscription Fee	x	x	
Contractor Installation	x	x	

As shown in the previous section, cable companies use their brand to set up home surveillance security system around the house to make package deals where the camera, the wifi and the applications are already immutable and installed. That is how companies get the upper hand because the majority of customers don't want to do the research; they prefer that everything is easy to set up. In addition, if the homeowner would not have to pay for an installation fee and can find a cheaper subscription, then it would ease the burden of cost. There are multiple projects, gadgets, and devices that can be found online with guides on how to install the equipment. The problem with that is just the variety of different cameras that can confuse a lot of customers on what product to use and what features are important.

4 Risks and Challenges

Due to the ambitious nature of the project, a proposed feature, an Android-based application for livestreaming, might not be implemented within the allotted time. This feature will be dependant on the duration of time expended for the major features (object detection and {glsrecognition). The team feels that the creation of a functional prototype with dependable

computer vision features and a web-based interface would trump a system with a rushed and buggy features.

4.1 Ethical Considerations

Under Massachusetts General Law, Interception of Wire and Oral Communications, it is permitted for a homeowner to record video surveillance of their home so long as the recording contains no audio [9]. Due to this constraint, the system will not include any method of recording audio.

Condominium owners, however, are subject to Massachusetts General Law Chapter 183A: Condominiums [10], and as such may or may not have the right to install a surveillance system should it impede in neighboring unit owner's right to privacy [11]. [1]

5 Bill of Materials

Table 4: Prototyping bill of materials.

Description	Vendor	ID	Unit Cost	Qty	Ext. Cost
Raspberry Pi 2 - Model B	Adafruit	2358	$39.95	1	$39.95
Raspberry Pi Camera Board	Adafruit	1367	$29.95	1	$29.95
WiFi 802.11b/g/n Module	Adafruit	814	$11.95	1	$11.95
8GB Class 10 SD/MicroSD	Adafruit	2692	$9.95	1	$9.95
5V 2A Power Supply USB Connector	Adafruit	1994	$6.95	1	$6.95
Log-scale Analog Light Sensor	Adafruit	1384	$3.95	1	$3.95
5mm IR LED 940nm	Adafruit	387	$0.75	10	$7.50
12' ft Micro-USB to USB Cable	Amazon	2185	$6.40	1	$6.40
SanDisk 32GB microSDHC Class 10	Amazon	B010Q57T02	$12.75	1	$12.75
Proto Armour for Raspberry Pi	MobileApp	100052	$35.00	1	$35.00
Total Cost:					$164.35

[1] This section does not constitute as legal advice and should not be acted upon as such. Please seek an attorney for clarification on your home surveillance rights.

6 Division of Labor

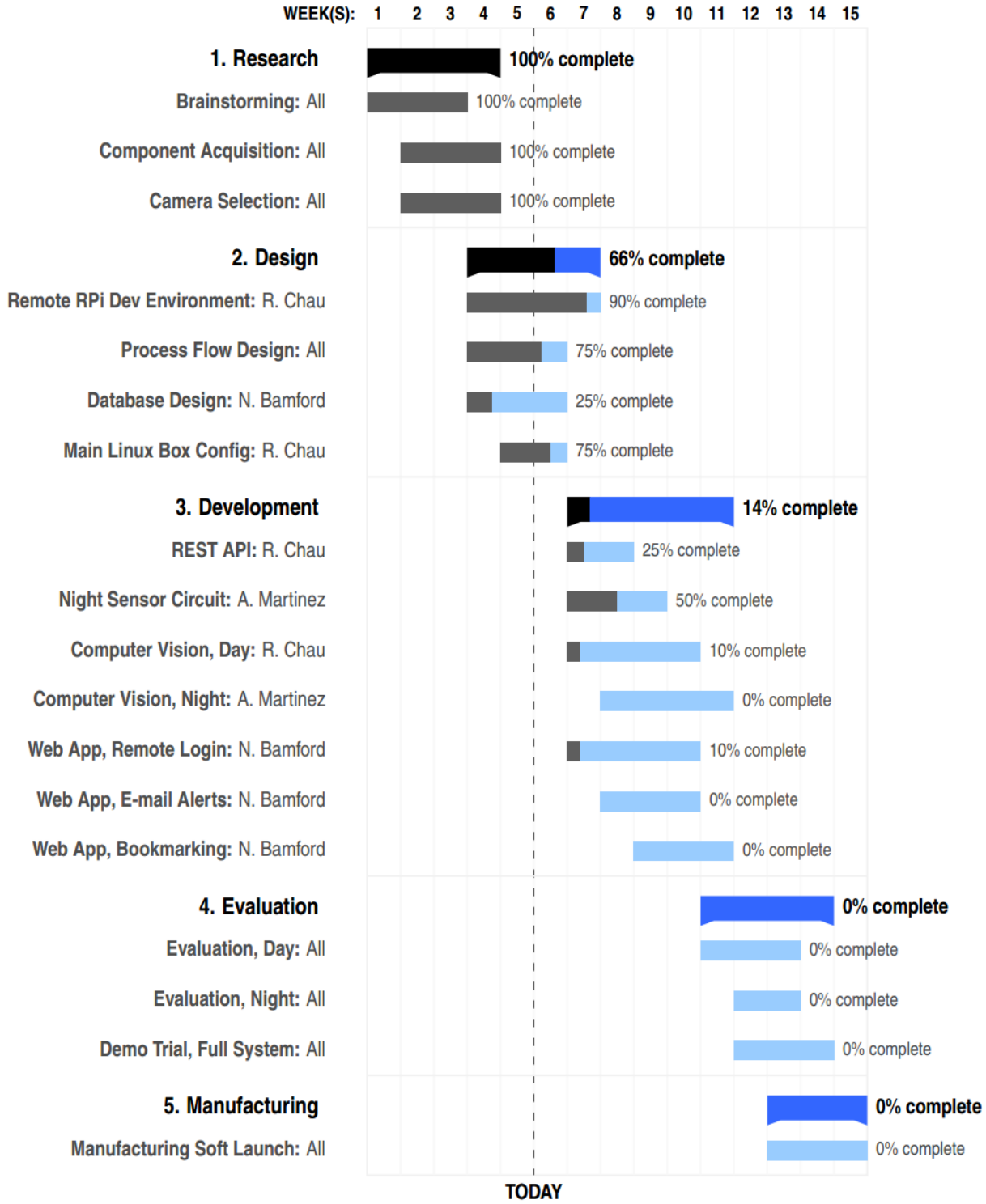

Figure 12: Progress as of 07 JAN, 2016, broken up by sprints.

Rather than following the waterfall development model that is prevalent in academia, this project will be largely executed through Scrum-based methodology [12, pp. 22-32]. As such, the completion dates for each task will be mutable. Scrum was chosen by the team due to its iterative and flexible nature; roadblocks such as the one encountered during *TASK 2: Remote Pi Dev Environment* can be bypassed for another task, thereby keeping the team's momentum moving forward [13].

Each week the team will meet at a minimum of 2 (not counting lecture block), but preferably 3 times in person. Each meeting will begin with a 5 minute maximum stand-up where each member will summarize:

1. What was accomplished since the last meeting.
2. Which task is being worked on.
3. Roadblocks or backlogs.

Finally, the Monday lecture block will be utilized as the daily stand-up meeting, thereby maximizing lab hours for development-related tasks.

6.1 Research Sprint

6.1.1 Brainstorming

- Research commercial residential security systems.
- Research computer vision algorithms.
- Build high-level block diagram.
- Configure ShareLaTeX repository.
- Configure Google Drive repository.
- Configure Dropbox repository.

6.1.2 Component Acquisition

- Perform cost analysis and build bill of materials.
- Purchase components.

6.1.3 Camera Selection

- Evaluate RPi camera module and USB-based webcam on RPi 2.

6.2 Design Sprint

6.2.1 Remote RPi Dev Environment

- Configure virtual environment for project.
- Set up Python wrappers for OpenCV and SimpleCV.
- Configure VNC and Adafruit WebIDE for remote access to prototype Raspberry Pi.
- Configure GitHub repository for version control.

6.2.2 Process Flow Design

- Build process flowchart based upon functional requirements.
- Build website UI flowchart.
- Build low level block diagrams, as needed.

6.2.3 Database Design

- Design entity-relationship database based on the functional requirements.

6.2.4 Main Linux Box Config

- Set up Linux Debian.
- Set up Apache web server.
- Set up MySQL database.

6.3 Development Sprint

6.3.1 REST API

- Develop (RESTful) Python API bindings to access MySQL database.

6.3.2 Night Sensor Circuit

- Calculate sensor model for light sensor.
- Build schematic.
- Breadboard IR LED array.

6.3.3 Computer Vision, Day

- Develop motion sensor feature.
- Develop human classifier–through SimpleCV Library–in Python.
- Develop car classifier–through SimpleCV Library–in Python.

6.3.4 Computer Vision, Night

- Trial daytime computer vision function during low-ambient conditions. Refine as needed.

6.3.5 Web App, Remote Login

- Develop a secure method to log into web app.

6.3.6 Web App, E-mail Alerts

- Develop the functions that will alert the user of movement.
- Refine alert constraints to reduce needless alerts.

6.3.7 Web App, Bookmarking

- Develop bookmarking system based on database design.
- Develop user-configurable history page. Pull a still image from each recording and embed–alongside metadata– the related record.
- Develop livestreaming by dynamically embedding recordings onto website.
- Develop charts based on detection history using Google Charts API, Plotly, or another data visualization graphing system with a Python wrapper.

6.4 Evaluation Sprint

6.4.1 Evaluation, Day

- Trial prototype based on the methods listed in the following section.

6.4.2 Evaluation, Night

- Trial prototype based on the methods listed in the following section.

6.4.3 Demo Trial, Full System

- Evaluate complete prototype. Refine as needed.
- Refactor code base.

6.5 Manufacturing Sprint

6.5.1 Manufacturing Soft Launch

- Create promotional video using the prototype.
- Cost analysis for 10,000 units.

7 Evaluation Methods

As part of the prototyping analysis phase, the system will be trialed during daytime, low ambient, and–weather permitting–heavy snow conditions. The trials will also focus on two major identification categories: Human and Vehicle.

7.1 Ambient Conditions

1. Daytime, clear view.
2. Daytime, snowy conditions.
3. Low ambient, clear view.

7.2 Human Identification

Four types of facial conditions will be used in the trials:

1. Human with uncovered hair and face, short hair.
2. Human with uncovered hair and face, shoulder-length hair.
3. Human wearing a hoodie.
4. Human wearing a baseball cap.

7.3 Vehicle Identification

Three types of vehicles will be used in the trials:

1. Black SUV
2. White Van
3. White Sedan

8 Conclusion

The design outlined in this proposal will allow for the deployment of a low cost, open source device capable of performing the constraints set forth. Careful research analysis and planning in design implementation will be maintained through the entire process in an effort to minimize disturbances to the research subject populations and conditions. Overall cost is reduced by a preference towards open sourced hardware and software. Features that increase usability in the low ambient conditions are also balanced into the product.

This design can evolve from the initial concepts through meetings with the researchers and prototyping trials. The Home Surveillance System will be able to accomplish data-gathering and metadata categorization of both humans and vehicles with strict identification abilities.

Calculations

$$Continual = \left(\frac{24\ hr}{1\ day}\right)\left(\frac{60\ min}{1\ hr}\right)\left(\frac{60\ sec}{1\ min}\right)\left(\frac{17\ mbit}{1\ sec}\right)\left(\frac{1\ byte}{8\ bit}\right)\left(\frac{1\ GB}{1737441824\ byte}\right)$$
$$= 170.99\ \frac{GB}{day}$$

Table 5: Known sightings during an average 24 hour day for a front door camera.

Type	Qty	Duration (min)	Sighting/24 hr	Total
Person	4	1	2	8
Dog	1	1	2	2
Delivery	2	1	1	2
				12 min

$$Floor = \left(\frac{12\ min}{1\ day}\right)\left(\frac{60\ sec}{1\ min}\right)\left(\frac{17\ Mbit}{1\ sec}\right)\left(\frac{1\ byte}{8\ bit}\right)\left(\frac{1\ GB}{1737441824\ byte}\right)$$
$$= 0.000014254\ \frac{GB}{day} \Rightarrow 0.014254\ \frac{MB}{day} \Rightarrow 14.254\ \frac{KB}{day}$$

Glossary

API Application Programming Interface is set of tools–usually in the form of a library–to build software-based components and to integrate various technologies.. 17, 18

blob Computer vision method that detects consistent regions within other regions.. 2, 3

detection Techniques to locate objects in still images or video sequences.. 2–4, 6, 13

Dropbox Cloud-based file hosting service that syncs similar-named directories across systems with the configured app.. 16

GitHub Online hosting service for git-based source code management and revision control.. 17

Google Drive Cloud-based file storage and sync service from Google used in this project to draft documents.. 16

Haar Object detection method by P. Viola and M. Jones, *Rapid Object Detection using a Boosted Cascade of Simple Features*.. 2, 3

LAMP Standard web service stack consisting of open source technologies such as Linux, Apache, MySQL, and Python.. 12

livestream Real-time Internet transmission of an event.. 9, 13, 18

MySQL My Structured Query Language is a relational database management system released on a GPL v.2 license.. 17

open source Software and hardware that is released to the public with a free license, allowing for universal access, distribution, and collaborative improvements.. 11

OpenCV Open Source Computer Vision is a computer vision library with an open-source BSD license developed at Intel.. 17

Plotly Online data visualization tool with scientific graphing libraries for Python.. 18

Raspberry Pi The Raspberry Pi is a series of sub-$50 single-board computers designed for educational usage. For the purposes of this document, all references–unless specified otherwise–refers to the Raspberry Pi 2 Model B.. 11

recognition Techniques to identify or verify objects in still images or video sequences through a stored database of known faces.. 2, 11

REST Representational State Transfer is an World Wide Web architectural

style for client–server communications.. 17

ShareLaTeX Online LaTeX editor with revision control and real-time collaboration.. 16

sighting In this case, each sighting is an interval of time where the system has detected an object.. i

SimpleCV Simple Computer Vision is a simplified version of OpenCV. Like OpenCV, SimpleCV is open source.. 11, 17, 18

sprint A basic unit of development in Scrum methodology. It is a timeboxed iteration that contains then existing backlog, current scope of work, and estimated commitment from each resource.. 15

stand-up A timeboxed meeting at the beginning of the team's workday where each resource gives an update on the events since the last stand-up, the plans for the day, and announces any roadblocks.. 16

VNC Virtual Computing Network is a system used to remotely control another computer.. 17

WebIDE Adafruit's web-based Integrated Development Environment designed for the Raspberry Pi.. 17

References

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[8] 2012, Learn, Sight Machine, from `http://www.simplecv.org/learn/index.html`

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[10] Mass. Gen. Laws c. 183A.

[11] Mass. Gen. Laws c. 214, § 1B.

[12] Pathak, P. Saxena, "Hybrid Methodology Involving Scrum and Waterfall Model towards the Software Project Development in Academic Knowledge Centers," International Journal of Evaluation and Research in Education, Vol. 1, No. 1, 2012.

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