Senior Design Spring ’21

Team 48

Team

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Client and Advisor

Dr. Daniels

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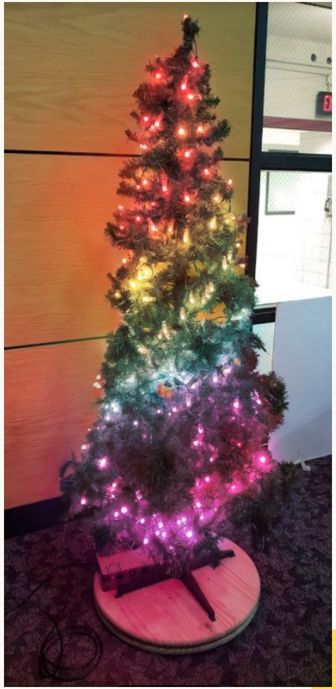
Problem Statement

Currently, in the marketplace there is very little support for creating a dynamic pattern of lights that are displayed on a Christmas tree and especially one that allows the user full control over each light.

So, to enhance the holiday experience Team 48's mission is to come up with a strategy to calibrate the LEDs in real time using a dual Raspberry Pi setup and image processing algorithm which allows the user to configure the patterns that are displayed on the spot.



Previous Teams - What we were given

- Completed control box with programmable string of LEDs (WS2811)
- Two Raspberry Pis (Tree Pi, Camera Pi)
- Website with two pages
- WIP calibration feature
- A few hardcoded patterns
- Prototype lazy susan

Plans/Goals to accomplish

- Fix calibration process
  - More accurate LED detection
  - Converting between coordinate systems
  - Better data structures
- Message queue on web application
- Dynamic pattern mapping and rendering
- Motorized lazy susan


```
{
    "num_lights": 3,
    "coordinates": {
        "0": [
            282.842712474619,
            45.0,
            300
        ],
        "1": [
            200.0,
            180,
            0
        ],
        "2": [
            180.27756377319946,
            326.30993247402023,
            400
        ]
    }
}
```

```
{
    "top": 100,
    "bottom": 700,
    "midpoint": 400,
    "num_lights": 4,
    "coordinates": {
        "0": {
            "0": [600, 400],
            "2": [300, 300]
        },
        "90": {
            "0": [200, 400],
            "1": [600, 700]
        },
        "180": {
            "1": [400, 700]
        },
        "270": {
            "2": [550, 300],
            "3": [400, 200]
        }
    }
}
```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Functional Requirements

- Easy to install
- Controlled remotely via web server
- Operate independently
- Calibrated with camera
- Calibration is easy to complete
- Display patterns/animations

Non-Functional Requirements

- Material cost under $100
- Calibration takes less than 1 hour
- Time to update patterns is less than 3 seconds

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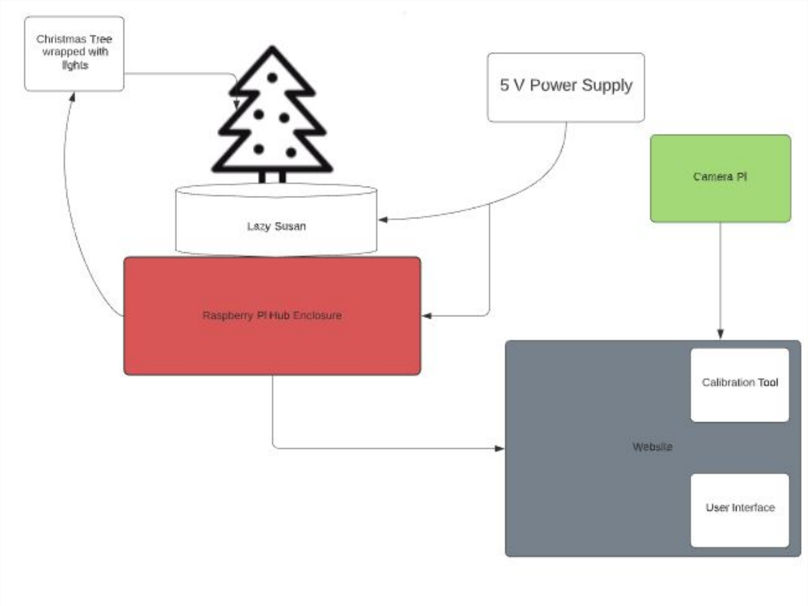
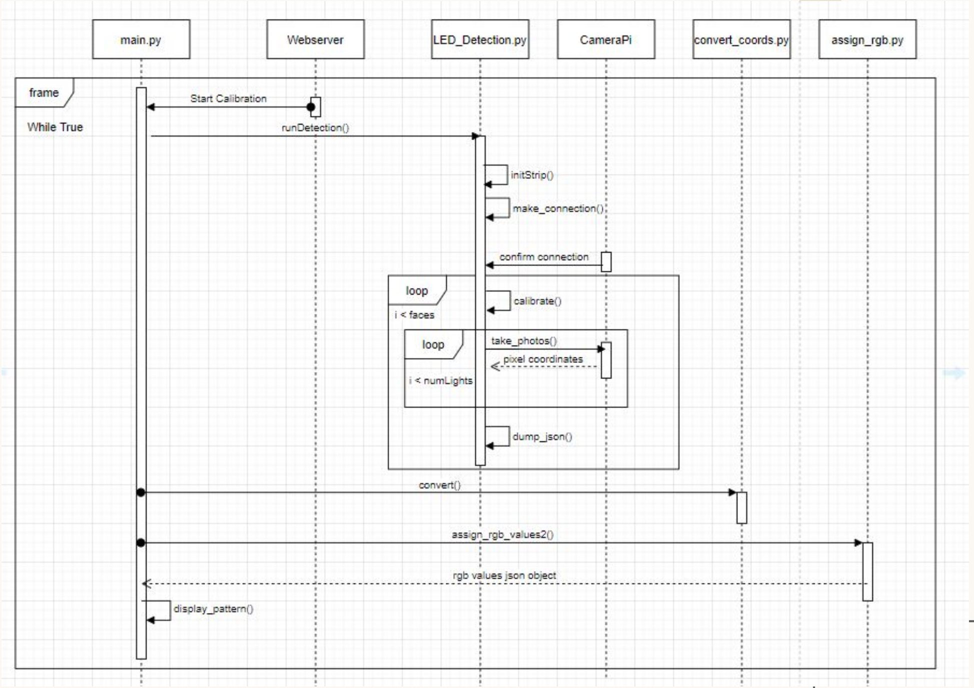
System Design





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Resources Requirements

Hardware

Two Raspberry Pi Model 3B/3B+

- Control Box
  - 12 V, 30 A power supply
  - LM2896 SMPS to step down 12V-6V
- Raspberry Pi Camera V2
- WS2811 LED strip
- ROB-12779 Stepper driver and ROB-10551 12V Bipolar stepper motor

Software

Apache HTTP Server

  - PHP
- Python 3
  - Paramiko(SSH)
  - OpenCV, and PIL (computer vision)
  - Numpy (data processing)
  - Rpi_ws281x (LED control)
  - ZeroMQ(message queue)

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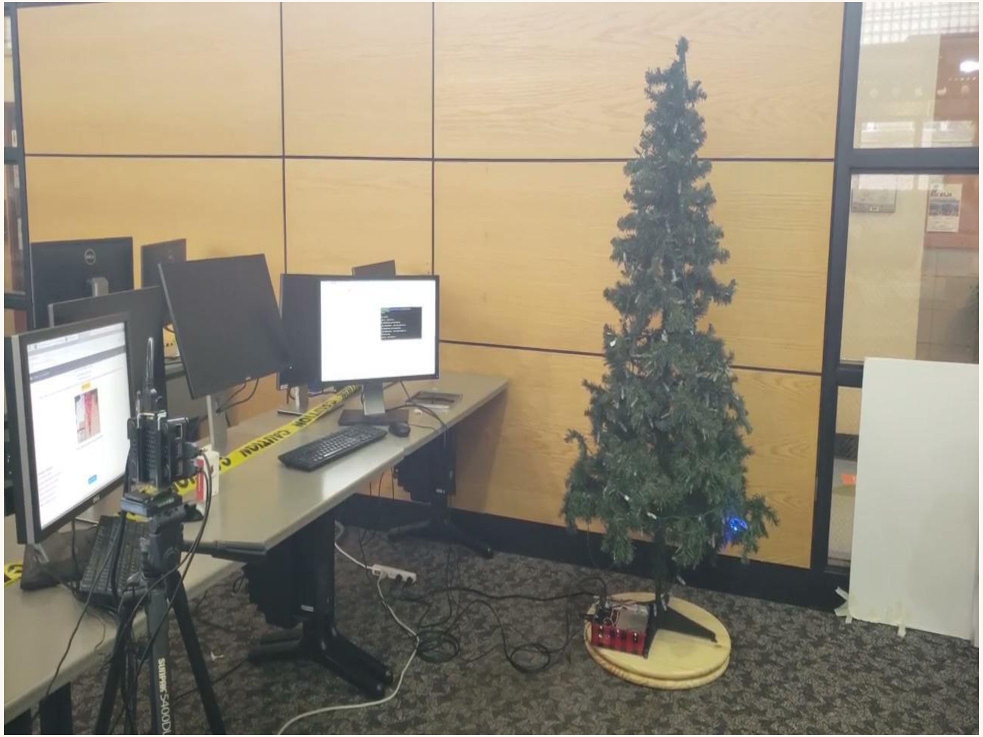
Results - What We Accomplished

- Replaced Raspberry Pis with fresh install
- Functional calibration with reliable light detection

  Using HSV filter, contours, and minimum enclosing circle from CV2

- Pattern rendering implemented and tested
- Main loop logic redesigned with message queue
- Construction of new Lazy Susan with setup for adding a stepper motor for automatic rotation
- Automated the turning of Wireless Access Point on, or off on Tree Pi

Demo - Successful Calibration Startup



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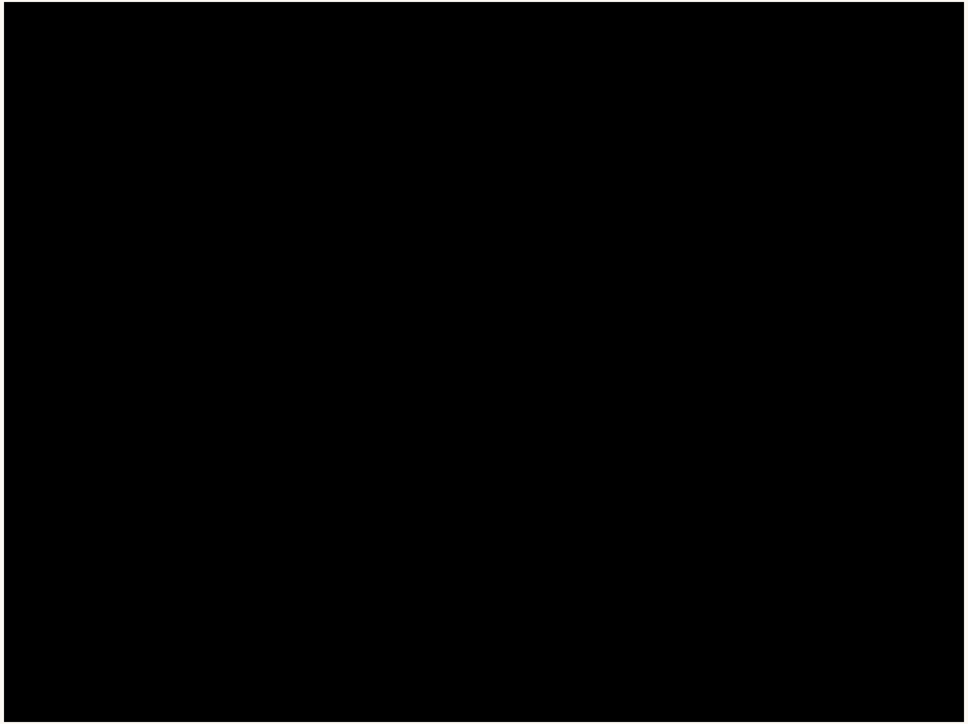
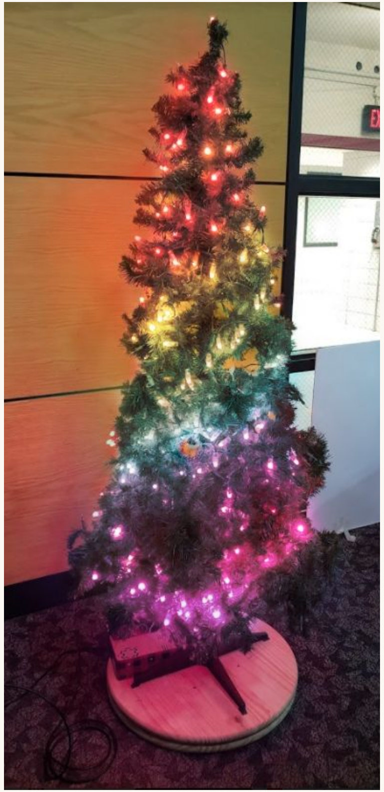
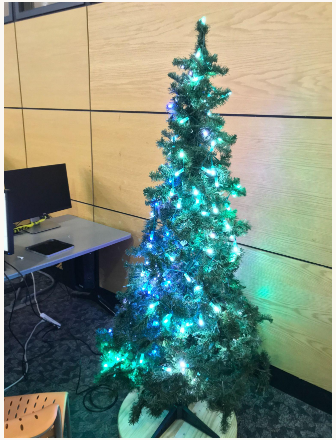
Demo - Time Lapse of 1 complete face



Demo - Successfully Rendered Patterns





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Biggest Challenges

Calibration

Existing code double-dipped with python 2.7 and 3.7 dependencies, making it impossible to run everything at once

Difficulties configuring WAP connection reliably on both Pis

Python 2 and 3 along with pip and its installed packages were associated incorrectly, presenting problems with installing new libraries

Calibration procedure took roughly 1.4 hours (5 seconds per LED multiplied by 250 for the total number of LEDs, and multiplied again by 4 for all the faces) - mainly due to image processing/ sleep time

Lazy Susan

Issue with how the stepper motor counts the steps - adjusted for an increased turning speed

Constraints and Considerations

Limited by Raspberry Pi

- Python libraries
- Wireless challenges

Pattern rendering

- On the fly

Early technical challenges

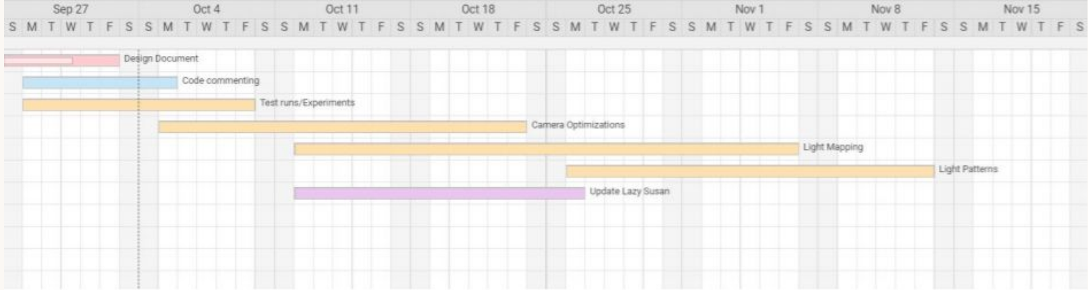
- Python versions
- File corruption/Pi issues

COVID-19 Lab Restrictions

- Reduced lab hours
- Reservations

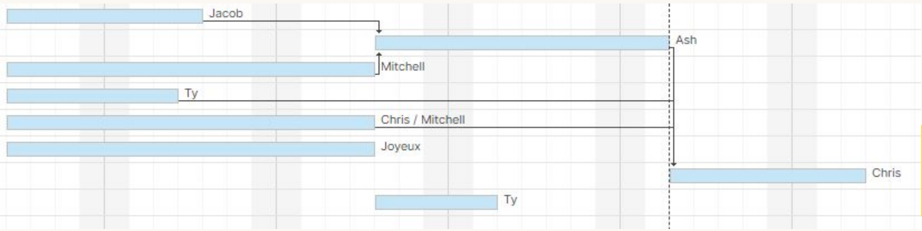
Schedule

Gantt chart for First Semester:



Gantt chart for Second Semester:

Task Name	Duration	Start	Finish	Predecesso...	Assigned To
Light Detection	6d	03/31/21	04/07/21		Jacob
Calibration Process	8d	04/15/21	04/26/21	1, 3	Ash
Lazy Susan	11d	03/31/21	04/14/21		Mitchell
Pattern Rendering	5d	03/31/21	04/06/21		Ty
Message Queue	11d	03/31/21	04/14/21		Chris / Mitchell
Website Pages	11d	03/31/21	04/14/21		Joyeux
Main Loop	6d	04/27/21	05/04/21	2, 4, 5	Chris
Access Point	3d	04/15/21	04/19/21		Ty



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Risks (Identification and Mitigation)

Software:

- Inaccurate Calibration
  - Mitigation strategy: try various techniques and test examples of code similar to what we are trying to accomplish until it is foolproof
- OpenCV
- Python
  - Mitigation strategy: fresh install of a RPi OS image on a new SD card

Hardware:

- Electric Shock
- Fire
- Burning out LEDs or Pis

Testing

Software

- Took pictures of lights under different lighting conditions to verify LED detection
- Created sample data to test coordinate conversion and pattern rendering
- Integrated components individually to observe errors and make sure everything is working together properly
- Ran code with debug statements to check program state at various points in the process

Hardware

- Ensure components given to us by the previous team were still in working order

Lessons Learned

- Create a well thought out specification and system architecture before major code efforts are done
  - Prevents code conflicts and miscommunications later on
- Use our instincts, especially when we get the feeling that something is wrong - and make mistakes early
  - For example at the start of this semester we felt like starting over for the calibration procedure, but we spent a few extra weeks trying to debug errors related to calibration and trying to get it to work. But we had to start over halfway through the semester with a new SD card and a fresh install of the RPi OS image
- Have confidence and trust our own judgment when making decisions
  - While this is cliché, it applies here because after multiple attempts at calibration, we realized that when we follow through with our own decisions we made progress much faster

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Future Work

- Finish functionality on the web application that allows the user to upload their own images that can be rendered onto the tree
  - Have preview images of what the pattern would look like on the tree
- Update pattern mapping to work with animated GIFs instead of just static images
- Finish the remaining work related to the Lazy Susan
  - Move the stepper motor so that it can generate more torque to move the tree

Questions/ Comments?

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