Recap: Use Case/Application

GOAL: Improve usability of computer monitoring for those who have to look at a screen for long periods of time

PRODUCT: Projection that follows the movement of a user's head

- Head detection/calculation in real time (<30ms)
- Motor responds to head movement: 95% accuracy
- Projection placement: 95% accuracy
- Full pipeline (<0.2s)

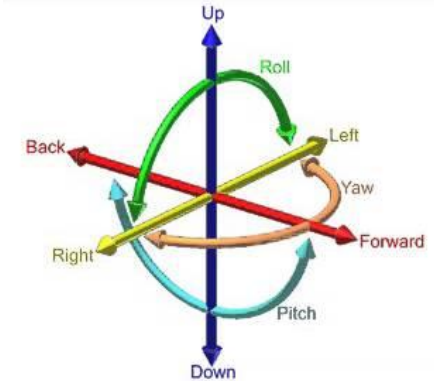
Recap: Solution Approach

Approach:

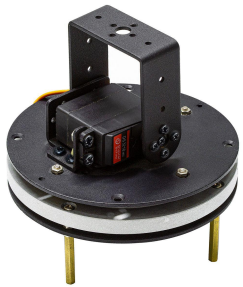
Camera detects head movement in order to align projection with user's line of sight

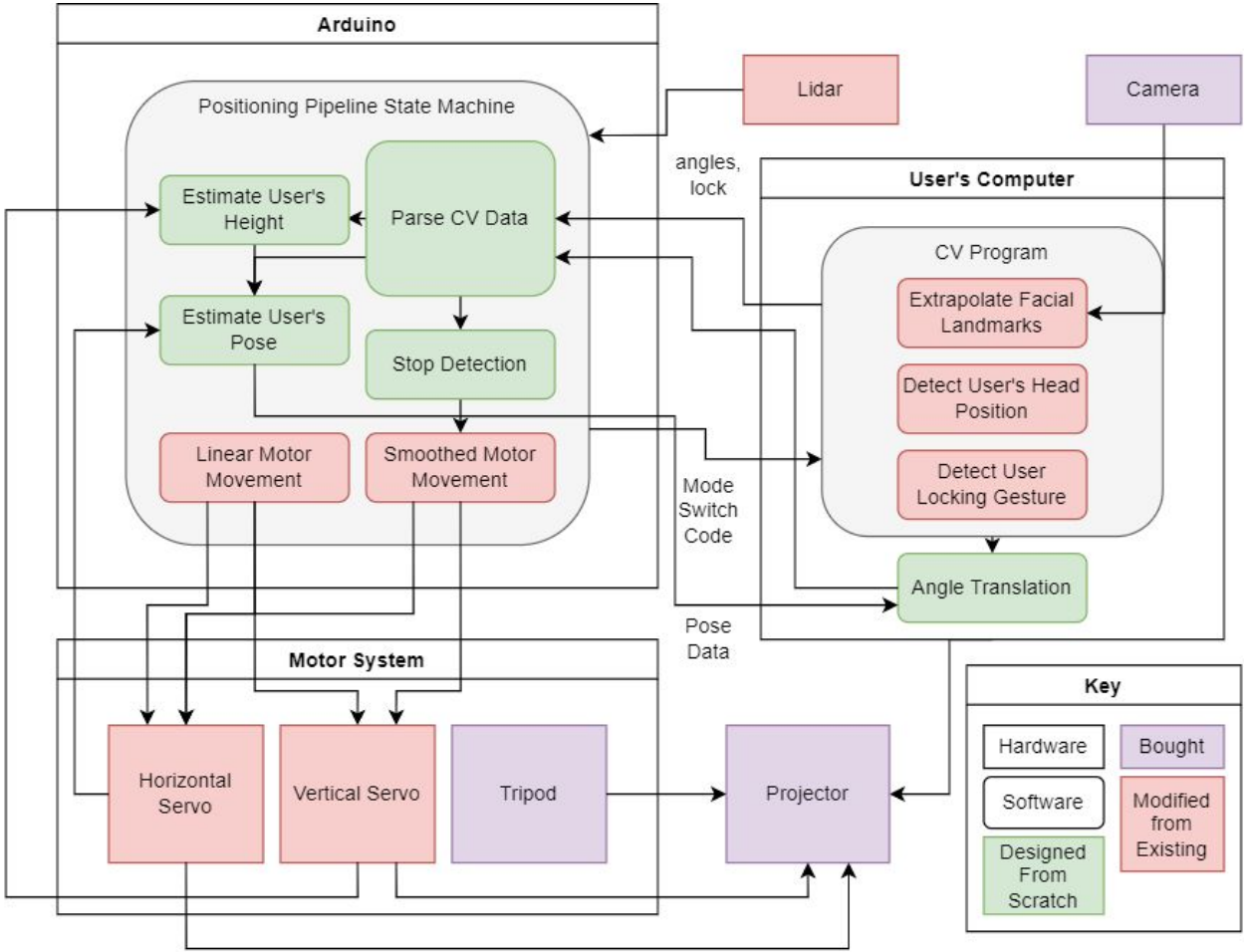
#1: Pose calibration process

#2: CV to calculate user's head rotation and movement



#3: Motor-controlled projector




Arduino
Positioning Pipeline State Machine
Estimate User's Height
Parse CV Data
Estimate User's Pose
Stop Detection
Linear Motor Movement
Smoothed Motor Movement
Lidar
Camera
angles, lock
User's Computer
CV Program
Extrapolate Facial Landmarks
Detect User's Head Position
Detect User Locking Gesture
Angle Translation
Mode Switch Code
Pose Data
Motor System
Horizontal Servo
Vertical Servo
Tripod
Projector
Key
Hardware
Bought
Software
Modified from Existing
Designed From Scratch

Changes from Design Review

Calibration Design/Arduino Program:

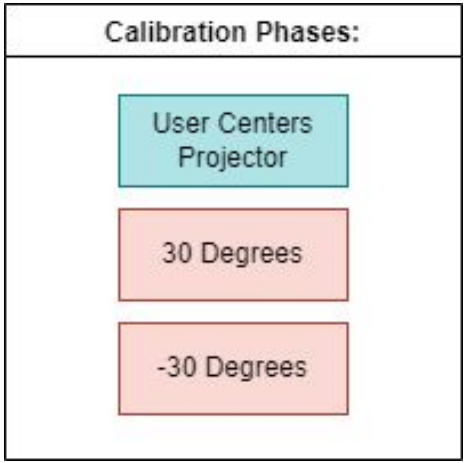
- Calibration is now 3-phase process
- Lidar + calibration pipeline have been restructured to run only in setup() code

CV Pipeline:

- Tuning for accuracy
- Added translation calculations

Motor System:

- Replaced vertical motor/batteries

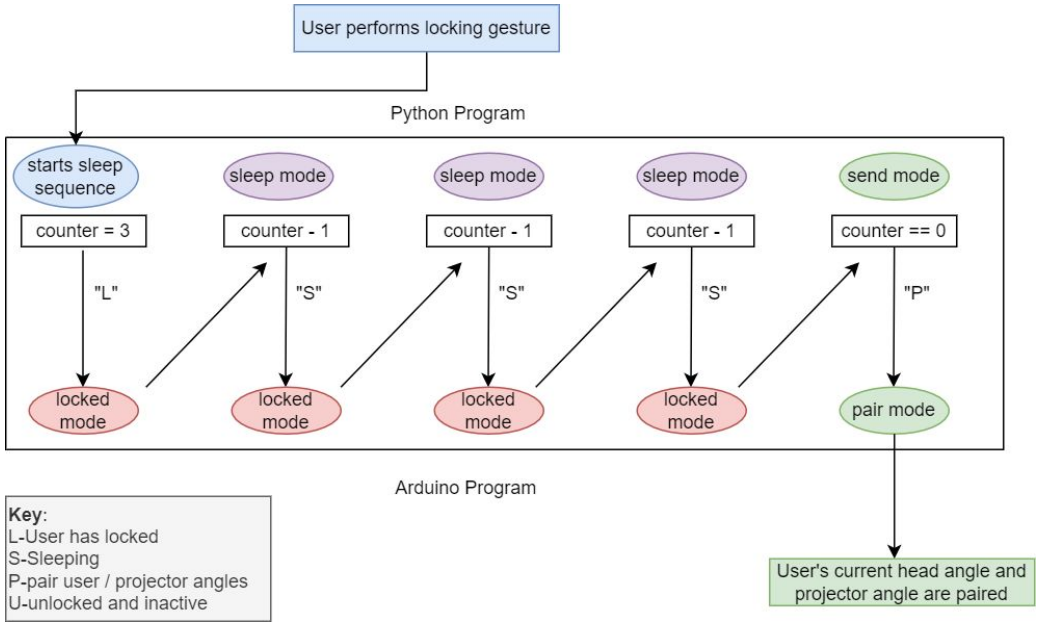


Changes from Testing: Robustness

Blurred user angle -> a delay between user locking the projector and then looking at the screen

Arduino-to-CV Communication:

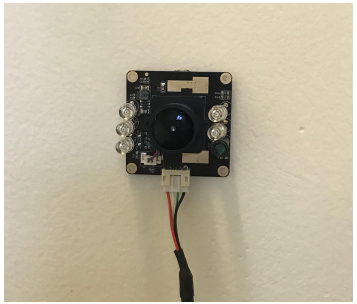
<FIN, [user-to-wall], [user-offset], [user-height], [wall_distance]>

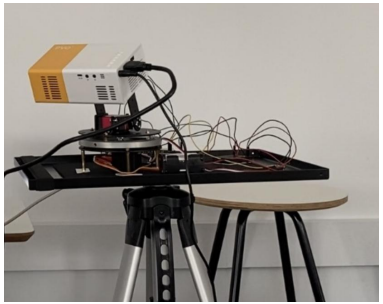


General Format: <[user_yaw], [user_pitch], [letter_code]>

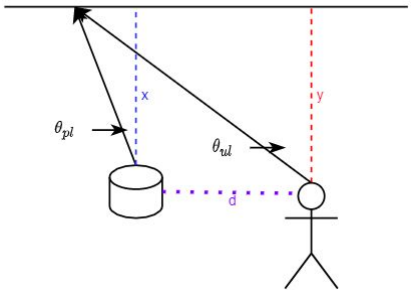
The pairing process

Complete Solution





- Adhesive camera put on a wall of choice
- Projector secured to a pan-and-tilt system controlled by two high torque servo motors
- User goes through a 3 phase calibration process - determine where the user is relative to the wall and projector (w/ LiDAR)
- Changes in head angle is translated to changes in motor(s) angles
- Motion of projector follows a cubic curve to match user's line of sight



Complete Solution: Quick Video

Test, Verification, and Validation

Requirements	Metrics	Test Plan
Gaze Estimation Speed	Real-time (< 30 ms)	Time from head movement to gaze estimation calculation
CV to motor pipeline latency	0.2 seconds	Time from when CV information is calculated to when motor moves
Motor responds to command	95%	20 Trials - Run function to move motor, respond incorrectly or not at all once
Projection placement accuracy	95%	20 Trials - Projection aligns with person's line of sight Error rate: 1 trial
System does not unnecessarily move	N / A	When user is making small movements (resulting in < 1 ft move in projection center), projection stays in place

Results

Requirements	Metrics	Results
Gaze Estimation Speed	Real-time (< 30 ms)	✅Yes
CV to motor pipeline latency	0.2 seconds	✅Pipeline ❌User's Full Movement
Motor responds to command	95%	✅Yes
Projection placement accuracy	95%	≈ Dependent on calibration
System does not unnecessarily move	N / A	✅Yes

User Testing

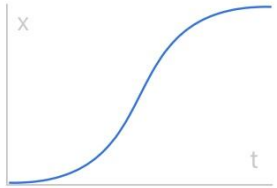
Goal: Find the most natural, comfortable motion for moving the projection from point A to B

Method: Test the following motion on 10 users

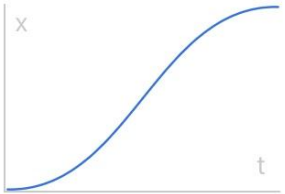
Speed (x, y %/s): Slow: (30, 15), Medium: (45, 22.5), Fast: (60, 30)

Easing Function: Linear, Cubic, Quadratic

Cubic



Quadratic



Results: The **fast speed** and **cubic easing function** resulted in the greatest user satisfaction

- Large panning distances were noted as very smooth
- Smaller panning distances were noted as a bit jerkier

Trade-Offs

Motor Smoothness vs. Lag Time

- Previously: Motor movement was jerky when following head pose but only had 0.3 second lag
- **Currently**: Motor movement is smoother but introduced 1 second lag when panning long distances because we wait to move the motor until the user has paused

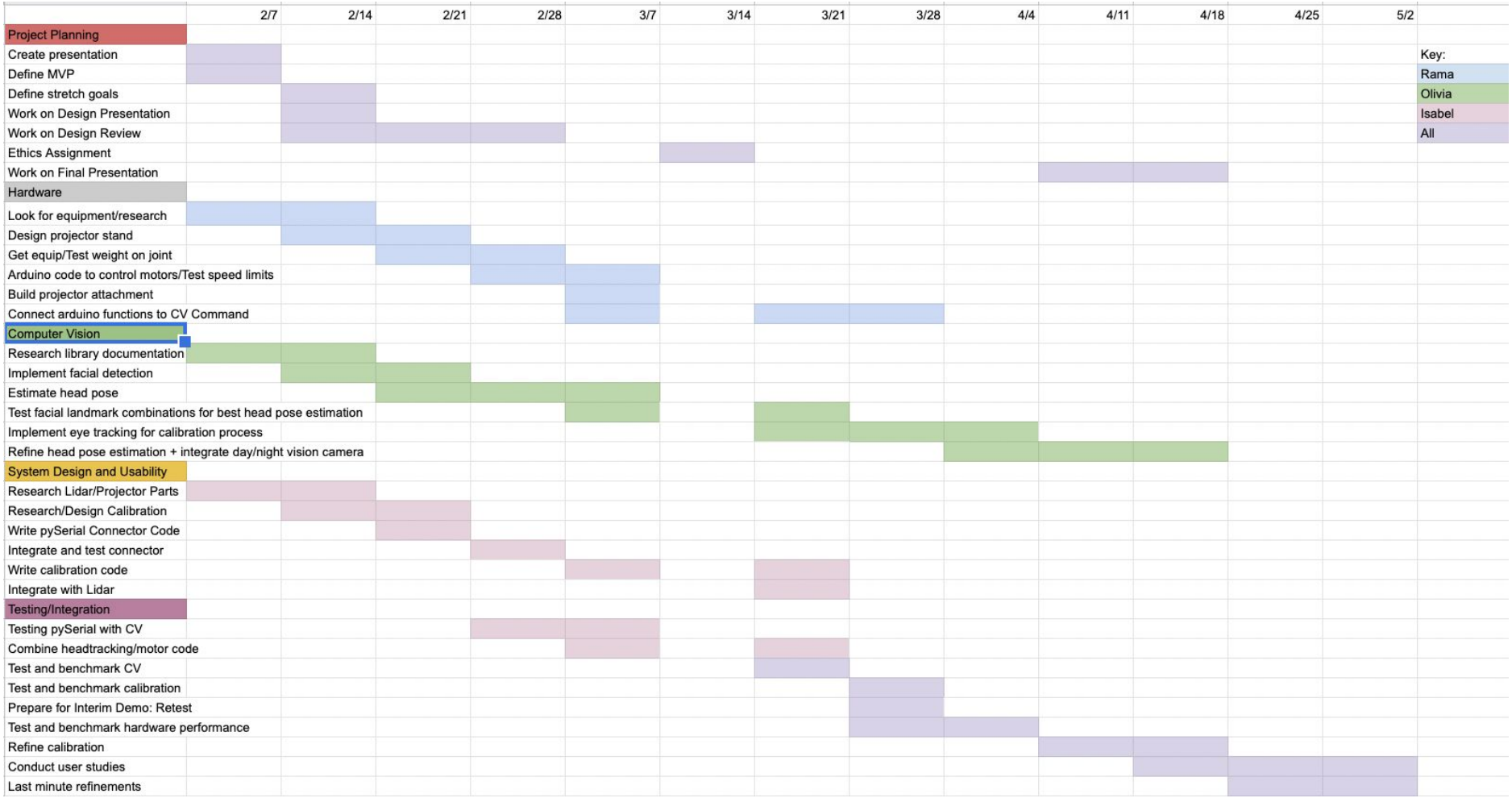
*This trade-off goes against our initial specifications but has resulted in greater user satisfaction

Motor Movement

- Users found the fast speed to align best with their movement but found it to be slightly jerkier than other speeds
- However, users prioritized fast motor speed over smoothness

CV Program Robustness vs. Accuracy

- Previously: Yaw and pitch were solely dependent on current frame being processed
- **Currently:** Yaw and pitch are averaged with their previous 5 values which decreases their immediate accuracy but makes the program more robust to error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2/14
2/21
2/28
3/7
3/14
3/21
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4/4
4/11
4/18
4/25
5/2
Project Planning
Create presentation
Define MVP
Define stretch goals
Work on Design Presentation
Work on Design Review
Ethics Assignment
Work on Final Presentation
Hardware
Look for equipment/research
Design projector stand
Get equip/Test weight on joint
Arduino code to control motors/Test speed limits
Build projector attachment
Connect arduino functions to CV Command
Computer Vision
Research library documentation
Implement facial detection
Estimate head pose
Test facial landmark combinations for best head pose estimation
Implement eye tracking for calibration process
Refine head pose estimation + integrate day/night vision camera
System Design and Usability
Research Lidar/Projector Parts
Research/Design Calibration
Write pySerial Connector Code
Integrate and test connector
Write calibration code
Integrate with Lidar
Testing/Integration
Testing pySerial with CV
Combine headtracking/motor code
Test and benchmark CV
Test and benchmark calibration
Prepare for Interim Demo: Retest
Test and benchmark hardware performance
Refine calibration
Conduct user studies
Last minute refinements
Key:
Rama
Olivia
Isabel
All