Project Projective

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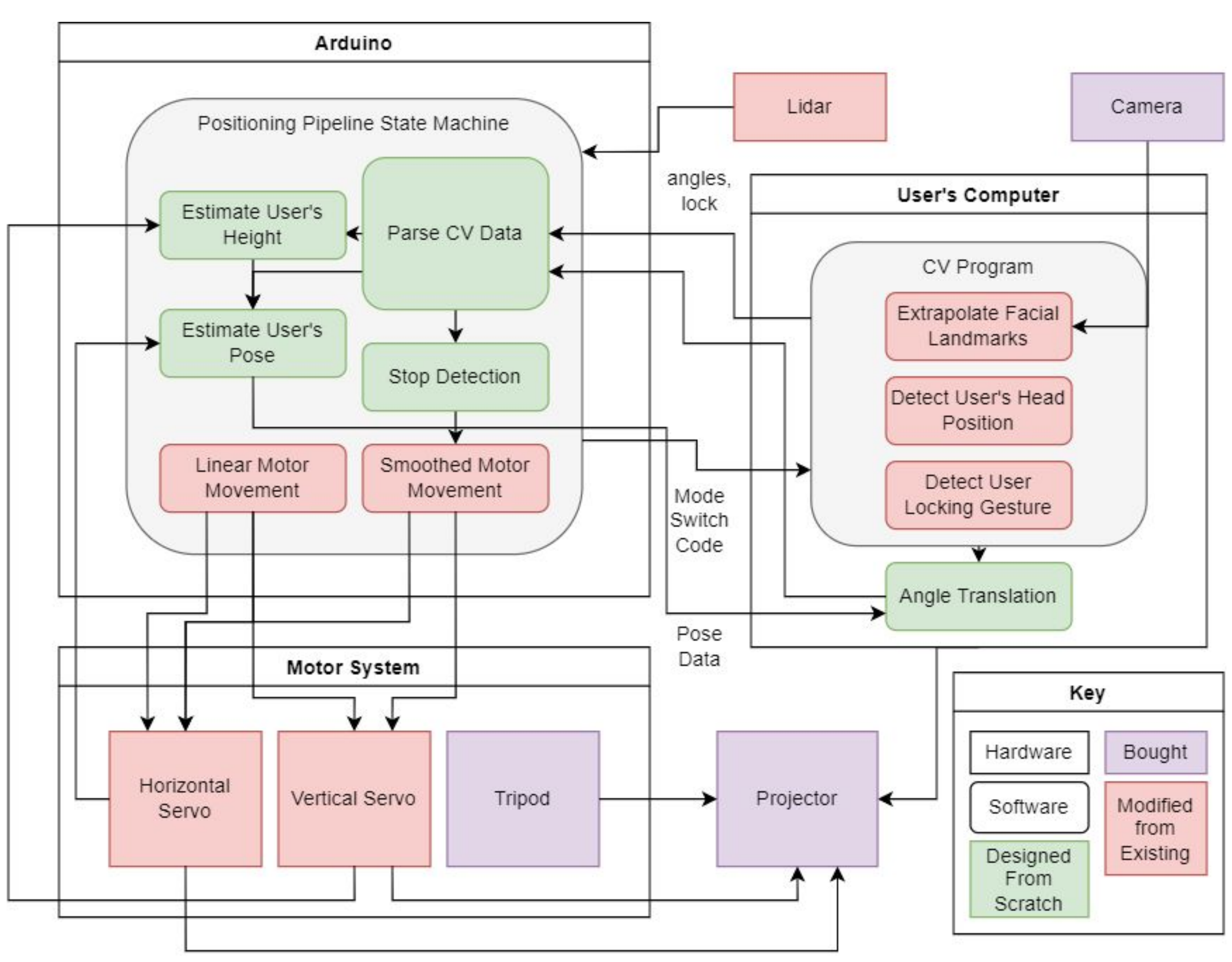
Product Pitch

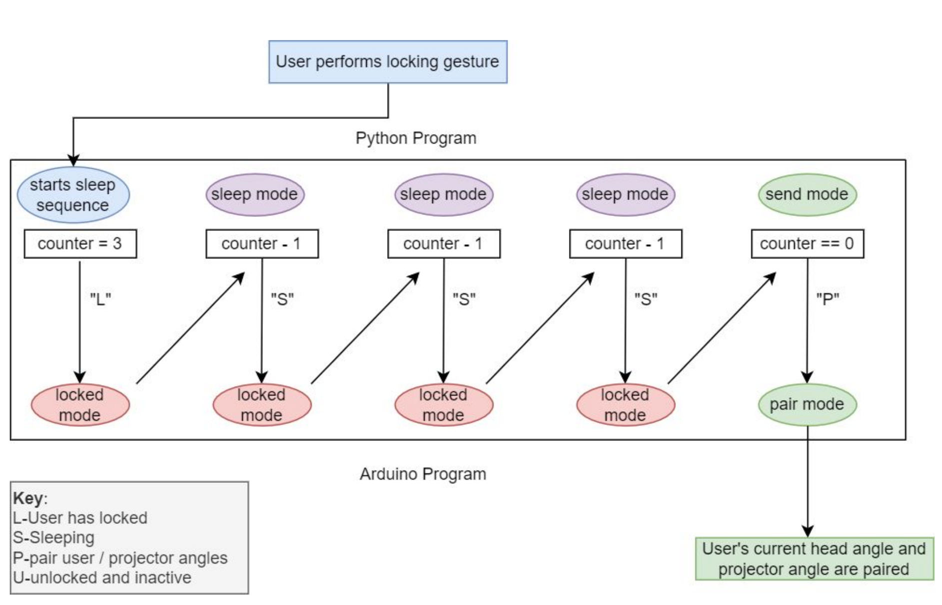
Neck pain, eye strain, and headaches are a common side effect from staring at a screen for extensive periods of time, an all-too-familiar experience nowadays. Our design alleviates this stress by having a projection of your screen follow your head gaze. Now, you can move your body, stretch your neck, and feel better during a work session while still focusing on the task at hand.

It is critical for the projection to position itself accurately 95% of the time and to follow the user's movement in almost real-time to create the most comfortable experience. Our system achieves these requirements quite well, with a lag time of 0.2-1 seconds and >95% accuracy when the calibration process goes well. Our project encompasess software, hardware, and signal and systems and underwent extensive user testing to identify the ideal motor movement.

System Architecture



Our system consists of 4 devices which communicate with each other simultaneously: the user's computer, the servos, the Arduino, and the lidar. The arduino controls a state machine and switches between states through codes sent by the CV program on the user's laptop.



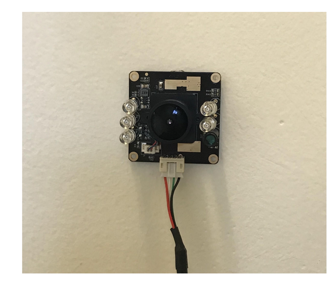
The different codes control the different phases of state switching: locking, sleeping, and pairing, which freeze the motor and wait for the user to get into position before pairing a user angle and projector angle. The user's position details are sent back to the user's computer, which then use these to perform the calculations to translate the user's angle to the projector's angle, so that they are aligned.

Conclusions & Additional Information

http://course.ece.cmu.edu/~ece500/projects/s22-teamc6/

Our project met our expectations in terms of its accuracy, speed, and smoothness, and we are very proud of it. Of course, we would have been ecstatic if there was no lag time between the head and motor movement. If we had more time, we would have integrated gestures to interact with the projection such as drawing or zooming in and out. Lessons learned include buying extra motors in case you catch yours on fire and having an MVP developed as soon as possible so you have ample for testing and fine-tuning.

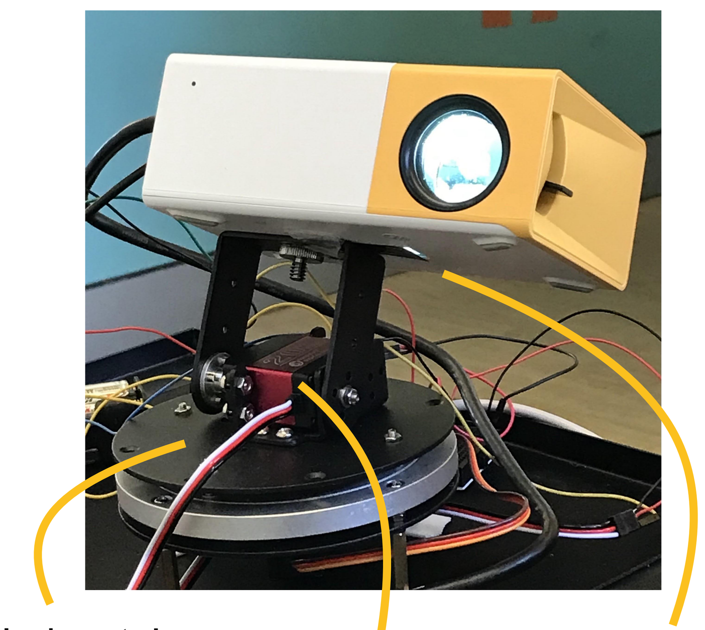
System Description



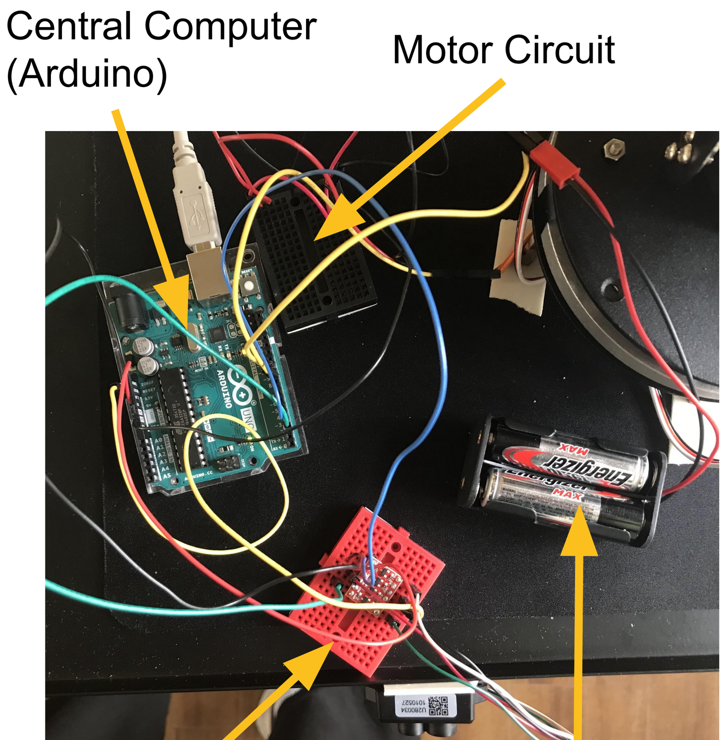
Camera

Our primary software component consists of a CV pipeline built using the MediaPipe library, which detects the user's head angle from the camera input.

The CV program feeds these angles and other state information to the calibration state machine on the Arduino. The calibration state machine pairs three detected angles with corresponding projector angles to determine the user's position in space, which later guides our motor system to line up the projection exactly with the user's gaze.



Motorized Projector Apparatus



Main Hardware and Circuitry

On the left is our main hardware system. The lidar circuit and the motor circuit house the communications between the arduino/lidar and arduino/motor.

Lidar Circuit: The lidar detects the distance between our projector and the wall, which also helps in our calculations of the user position.

Motor Circuit: The motor system is powered by our battery module. The motors are controlled by values from the arduino, but the arduino also takes the motor's position into account while performing the calibration process and calculating the user position.

System Evaluation

Testing Results

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

We conducted a user study on 10 students to find the most natural, comfortable motion for moving the projection from point A to B.

- Each user tested 3 easing types at 3 different speeds each
- Easing types: linear, quadratic, cubic
- Speeds (x, y in deg/sec): (30, 15), (45, 22.5), (60, 30)
- Users preferred cubic and the fastest speeds and thought larger panning distances were smooth and smaller panning distances were jerkier

Quadratic

Cubic

We conducted another user study where we tested the setup at various positions to see if speed should depend on distance from the wall. We placed the projector at 1m and 4m and found that the speed should depend on the size of the angle sweeps instead. Thus, the motor moves slower for smaller angle sweeps and faster for larger angle sweeps.

We noticed a tradeoff between motor smoothness and lag time. We improved smoothness by detecting when a user has stopped moving in either degree of motion. Users preferred a smaller lag time to smoothness so we stopped here to minimize lag time. There is also a tradeoff between the robustness of the CV program and accuracy. We decided to gather several values of user's head angles to determine a user's gaze. This made the system immediately less accurate but overall more robust.