Self-Adjusting Monitor Stand

ECE 445 Project Proposal

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1. Introduction

1.1. Problem

Certain monitor technologies today have fairly tight viewing angles, and viewing your computer screen from more than 30-45 degrees off the normal will often introduce visual artifacts that make it difficult to read [1]. However, most consumer monitor stands are not well adjustable, and it would be time consuming to constantly tweak the position to match every possible viewing angle. Additionally, many workplace environments require the use of privacy screens, which are designed to limit the field of view as much as possible, only exacerbating the problem. We aim to break this tradeoff between greater privacy and ease of use.

1.2. Solution

To improve a monitor that both provides privacy within a public setting as well as user viewing ease, we want to implement a monitor stand that automatically adjusts the screen to the user's position. This monitor stand will have both automatic and manual components. For the automatic components, the user's position will be detected by a camera, and the monitor will adjust its location to an angle. The height of the monitor will also be adjustable to the user's preference by using a linear actuator.

For the manual component, the user can press buttons on the attached remote. The horizontal pan is physically adjusted through a gear that is between the mounting box and the actuator, while the vertical tilt is attached to the monitor The motors involved in these adjustments will include encoders to ensure the appropriate. The height adjustment is purely based on the user's input. The viewing angle, or the pan and tilt, will be determined by the user's location when a command is given to adjust the screen.

1.3. Visual Aid

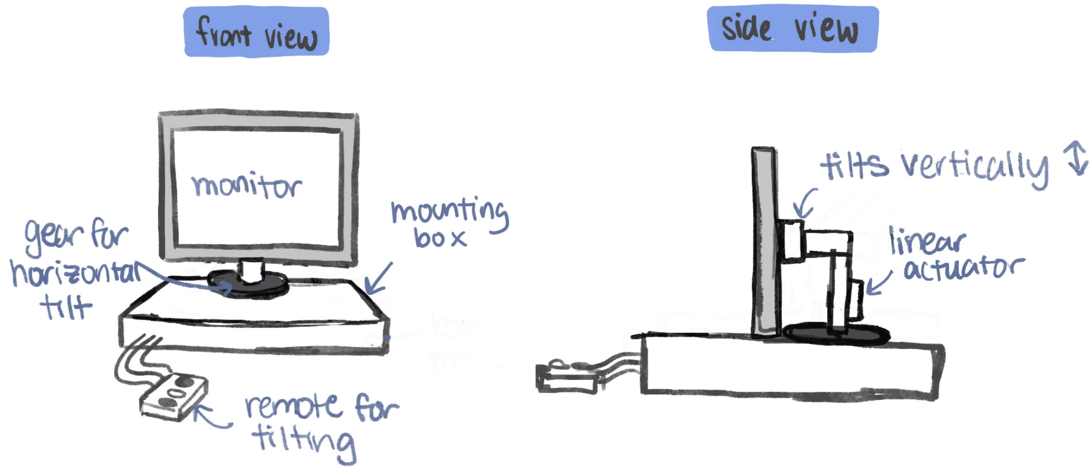

Figure 1. Simple sketch of the monitor stand and remote

1.4. High-level Requirements

1.4.1. Detection and Adjustment: If the "adjust" button is pressed, the monitor stand should pan and tilt the monitor so that it is centered on the user within 10 degrees both vertically and horizontally. See Figure 2.

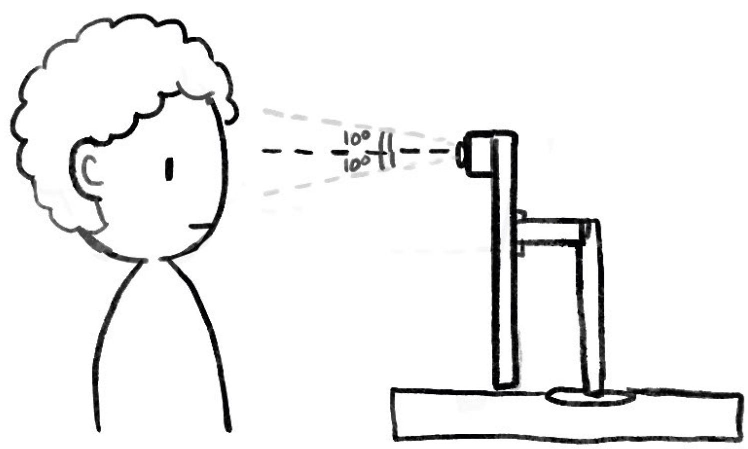

Figure 2. Depiction of desired accuracy in the vertical direction.

1.4.2. Vertical Positioning: If the "up" or "down" button is pressed, the system should raise or lower the monitor until the button is released or the linear actuator reaches the maximum or minimum height at a minimum rate of 2 cm/s.

1.4.3. Reasonable Response Speed: The system must adjust the angle of the monitor to be centered on the user (according to requirement 1.4.1) within 6 seconds.

2. Design

2.1. Block Diagram

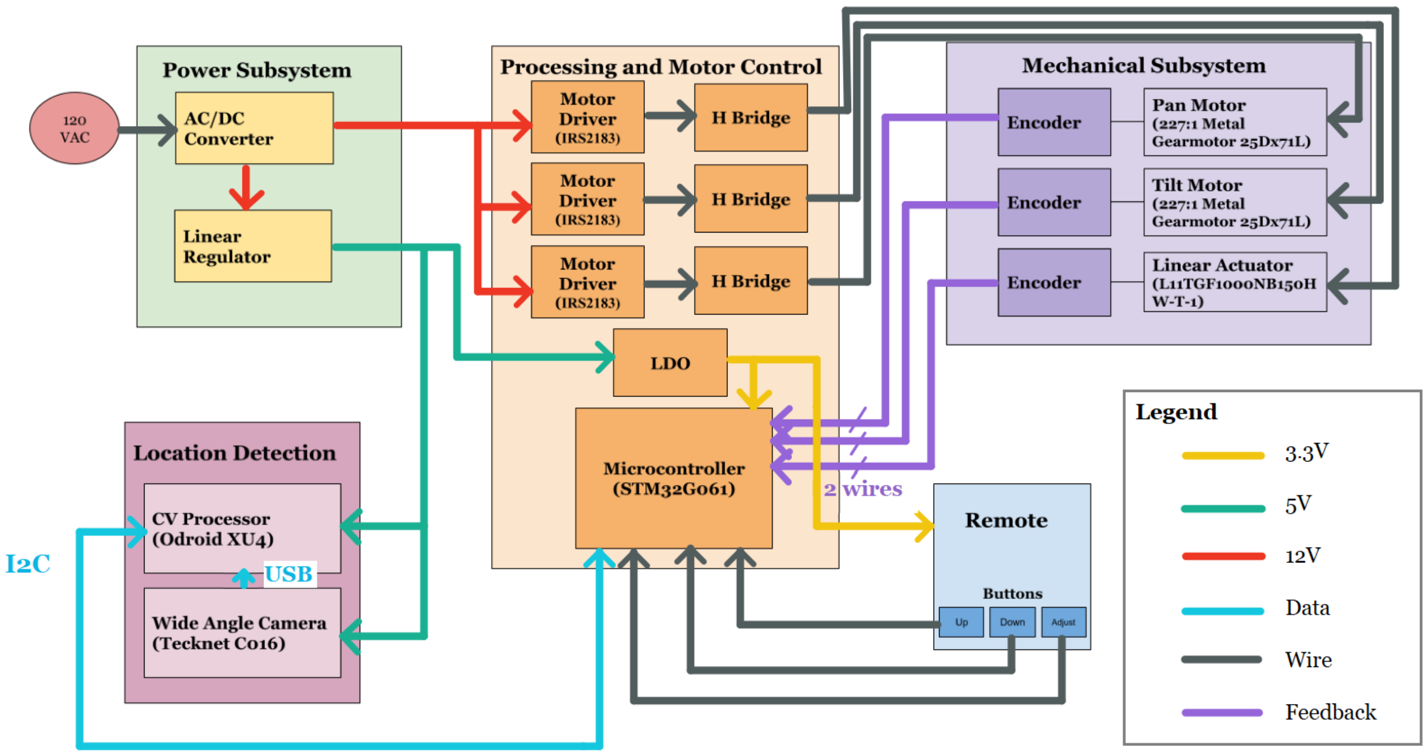

Figure 3. High-level block diagram of the monitor stand and remote.

2.2. Subsystem Overview and Requirements

2.2.1. Power Subsystem

The entire project will be powered using a wall adapter, which introduces the need for this subsystem. The power subsystem will convert the input from AC to DC so that the various components in our device will be appropriately powered. This subsystem will also create a 12V and a 5V power rail to accommodate the different voltage requirements of each component.

Requirement: Convert 120VAC to 12V±1V and 5V±1V power rails. 5V rail should have a 10A capacity, and the 12V rail should have a 15A capacity.

2.2.2. Location Detection Subsystem

A core aspect of this project is the ability to detect the user and use that location to adjust the monitor. The location detection subsystem will consist of a USB camera and a computer vision (CV) processor. We have decided to use an Odroid XU4 to serve as the processor in this project. Both main components in this subsystem will be powered using the 5V rail. The camera will connect to the processor by USB, and the processor will send data to the microcontroller in the processing and motor control subsystem using the I2C protocol.

Requirement 1: Image processing should occur at 15 FPS to ensure accurate face detection without overly heavy computation [2].
Requirement 2: The processing unit must be able to quantitatively determine how much the monitor must pan and tilt to be centered on the user within 10 degrees.

2.2.3. Processing and Motor Control

This subsystem will use information from the user and the camera to control the vertical, pan and tilt motors. The main components in this subsystem are the microcontroller and MOSFET motor drivers. The microcontroller will be powered using a low-dropout regulator (LDO), which will step-down 5V from the power subsystem to 3.3V.

Signals from the user will be sent to the microcontroller, which will then communicate with the motor drivers. If the microcontroller receives a signal to move the monitor up or down, it will communicate that information to the motor driver. The appropriate motor driver will use this signal to control the linear motor. If the microcontroller receives a signal to adjust the monitor angle, it will first access data from the CV processor to determine the position of the user relative to the center of the monitor and to determine how far the monitor must pan and tilt. Encoders on the motors will send feedback to the microcontroller whenever there is movement to ensure that the monitor is adjusted appropriately.

Requirement 1: LDO regulator should step down 5V to 3.3V±1V for microcontroller use.
Requirement 2: Microcontroller should not miss encoder steps at normal operational speeds.
Requirement 3: Motor drivers should each supply 5A to each motor without excessive overheating.

2.2.4. Wired Remote Control

The user interface for this system will be a wired remote with three buttons: an “up” button, a “down” button, and an “adjust” button. When a button is pressed, a signal will be sent to the microcontroller in the processing and motor control subsystem. The monitor stand will respond accordingly by moving up, down, or adjusting the angle of the screen with respect to the user. For vertical adjustment, the buttons must be held down until the monitor is at the desired position. For the angle adjustment, the “adjust” button should be pressed once. The buttons will be powered using 3.3V, which is accomplished by stepping down the voltage from the 5V rail.

Requirement: The remote will communicate with the processing unit via a 3 foot cable.

2.2.5. Mechanical Components

2.2.5.1. Vertical

In order to physically move the monitor, a vertical mechanical subsystem is required. This unit will consist of a linear actuator and an encoder. Based on the signal from the motor driver, the linear actuator will adjust the monitor height. The encoder will provide feedback to the microcontroller to keep track of how much movement has occurred.

Requirement 1: The linear actuator assembly should have 6 inches of travel.
Requirement 2: The surface temperature will not exceed 115℉ [3].

2.2.5.2. Pan

There will also be a subsystem to allow the monitor to pan. This will be accomplished using a rotating platform that will allow the monitor to turn to the right or left. The microcontroller will send a signal to the motor driver, which will send a signal to the pan motor. This motor will be a 12V DC motor with a reduction gearing attached. This will actuate a worm drive system to turn the monitor. The encoder will provide feedback on how much the motor has turned so that the monitor will stop when it is centered on the user within 10 degrees.

Requirement 1: The pan motor assembly should have 90 degrees of travel (45 degrees in each direction).
Requirement 2: The surface temperature will not exceed 115℉ [3].

2.2.5.3. Tilt

Similar to the pan mechanical subsystem, there will also be a subsystem to allow the monitor to tilt. This will be accomplished using a motor that will tilt the monitor screen up or down.. The microcontroller will send a signal to the motor driver, which will send a signal to the tilt motor. This motor will be a 12V DC motor with a reduction gearing attached. The motor will drive another worm gearing to tilt the monitor. A worm drive system ensures that gravity cannot backdrive the motor easily. The encoder will provide feedback on how much the motor has tilted the monitor to ensure it is centered on the user within 10 degrees.

Requirement 1: The tilt motor assembly should have 30 degrees of travel.
Requirement 2: The surface temperature will not exceed 115℉ [3].

2.3. Tolerance Analysis

One of the most challenging and important aspects of our project is the ability to detect the location of a person in front of the monitor using a camera and computer vision. Being able to train and efficiently recognize the human face from a video input affects almost every aspect of our design because the horizontal pan and vertical movement is automatic based on where the user is.

First, we will use Haar features instead of having the convolutional neural net learn which features to look for. Haar features are better for recognizing edges, as long as the user's face is not obscured. This allows us to create a classifier with a smaller dataset.

Haar features split up the window into various sections. The pixels in these sections are added, and the difference between them is calculated. Summing all the pixels in a window can be inefficient. If we use integral images, which set the value of the pixel at (x,y) to the sum of the pixels above and to the left of it, the sum of all the pixels in a given window can be calculated in O(1) time, rather than O(n), where n represents the window area [4].

However, the number of Haar features can be quite large depending on the size of the window. If we analyzed the image with a 24x24 window, there would be 160,000+ possible Haar features. We will use the boosting technique, AdaBoost, in order to find which features are the best to use [4]. This algorithm works by repeatedly changing the weights of the haar features until it meets a minimum error rate, with a final classifier of the weighted sum of the weak classifiers. This can allow us to use just even 200 features with a 95% accuracy [5].

Finally, when analyzing the image, much of it will be background instead of the user. Instead of passing all 200 features in a single window, we first check if the window is a face through a cascade classifier that groups features into stages. If it doesn't pass all the stages, the region is classified as a "non facial region," and it will not be analyzed again.

These techniques will allow for fast, robust face detection within our camera's field of view. Various other techniques can be applied to improve the positive detection rate for differing backgrounds and situations. By tailoring our algorithm to solve any significant new problems encountered, we are confident that the Location Detection subsystem will function as intended.

3. Ethics and Safety

One of the major ethical concerns in our system is the potential for privacy invasion. The monitor stand uses a camera to identify where the user is sitting and processes the image data to determine how the monitor should be moved. Section I.1 of the IEEE Code states that we must "protect the privacy of others" [6] and Section 1.6 of the ACM Code of Ethics states that "an essential aim…is to minimize negative consequences of computing, including threats to health, safety, personal security, and privacy" [7]. To ensure the privacy of the user is protected, the camera image will only be accessed internally by the processor when necessary. There will be no long-term storage of any image data, and the images will not be used for any purpose other than calculating the necessary monitor adjustments.

Another ethical consideration related to the detection of the user. A common issue in detection and facial recognition is the disparity of detection between races and skin tones. It is our responsibility to treat everyone fairly and avoid engaging in any kind of discrimination based on color or race [6, 7]. We shall do our best to address this problem by selecting training datasets that contain faces of various races and skin tones.

Additionally, there are safety considerations that must be made regarding the system. The IEEE Code of Ethics states in Section I.1 that we must "hold paramount the safety, health, and welfare of the public" [6]. Section II.9 also states that we must consider how our system could injure others or their property. In our proposed design, we are limiting the speed at which the monitor moves to prevent damage, and we are addressing user safety concerns by requiring that the surface temperature of the device remain below 115℉ and by controlling the current through the motor.

References

[1] Kaelee Nelson, “Why Do I Need a Computer Privacy Screen?” *HP Development Company, L.P.,*11-Jan-2019. [Online]. Available: https://www.hp.com/us-en/shop/tech-takes/why-do-i-need-computer-privacy-screen. [Accessed: 5-Feb-2022].

[2] “Basic rules for a successful facial biometrics project,” *RecFaces*, 11-Aug-2021. [Online]. Available: https://recfaces.com/articles/basic-rules-for-a-successful-facial-biometrics-project. [Accessed: 10-Feb-2022].

[3] A. Rowe, “Safe Workplace Touching Temperatures,” Safety Action, 5-Jul-2018. [Online]. Available: https://www.safetyaction.com.au/blog/safe-workplace-touching-temperatures. [Accessed: 8-Feb-2022].

[4] Gupta, Rohan. “Breaking Down Facial Recognition: The Viola-Jones Algorithm.” *Medium*, Towards Data Science, 12 Feb. 2020. [Online]. Available: https://towardsdatascience.com/the-intuition-behind-facial-detection-the-viola-jones-algorithm-29d9106b6999. [Accessed: 10-Feb-2022]

[5] “Using AdaBoost to Minimize Training Error.” *MIT Press*. [Online]. Available: https://mitpress.mit.edu/sites/default/files/titles/content/boosting_foundations_algorithms/chapter003.html. [Accessed: 10-Feb-2022].

[6] “IEEE Code of Ethics,” *IEEE*, Jun-2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 1-Feb-2022].

[7] “ACM Code of Ethics and Professional Conduct,” *ACM*, 22-Jun-2018. [Online]. Available: https://www.acm.org/code-of-ethics. [Accessed: 1-Feb-2022].