ECE 445
Senior Design Laboratory
Design Document

Smart Tripod

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Table of Contents

1. Introduction........3
1.1 Problem........3
1.2 Solution........3
1.3 Visual Aid........4
1.4 High Level Requirements........4
1.4.1 Motor Accuracy and Responsiveness........4
1.4.2 iPhone Camera Action and Responsiveness........4
1.4.3 Airplay and Tracking Responsiveness........4
2. Design........5
2.1 Block Diagram........5
2.2 Subsystem Overview and Requirements........5
2.2.1 Remote Display / Controller System........5
2.2.1.1 Power Subsystem........5
2.2.1.2 Control / Network Subsystem........6
2.2.1.3 Video Feedback Subsystem........7
2.2.2 Motorized Tripod System........7
2.2.2.1 Power Subsystem........7
2.2.2.2 Control Subsystem........8
2.2.2.3 Motor Subsystem........8
2.2.3 iPhone App Integration System........9
2.2.3.1 App Subsystem........9
2.3 Tolerance Analysis........10
2.3.1 WiFi WebSockets Delay........10
2.3.2 Airplay Streaming Delay........12
2.3.3 OpenCV Processing Delay........13
2.3.4 Total Delay of System and Conclusion........14
3. Ethics and Safety........15
3.1 Privacy and Surveillance........15
3.2 Bias in Computer Vision Tracking........15
3.3 Transparency and Honesty........16
3.4 Accessibility and Inclusivity........16

1. Introduction

1.1 Problem

Traditional tripods provide stability for cameras and smartphones but lack dynamic adjustability and real-time framing assistance. When setting up a shot, users must manually adjust the tripod’s angle and position, often requiring multiple iterations to achieve the perfect frame. This process can be frustrating and time-consuming, especially for solo photographers, vloggers, or group shots where precise positioning is essential. Additionally, traditional tripods do not adapt to movement, making them impractical for scenarios where the subject may shift position, such as recording personal videos, filming demonstrations, or capturing action shots.

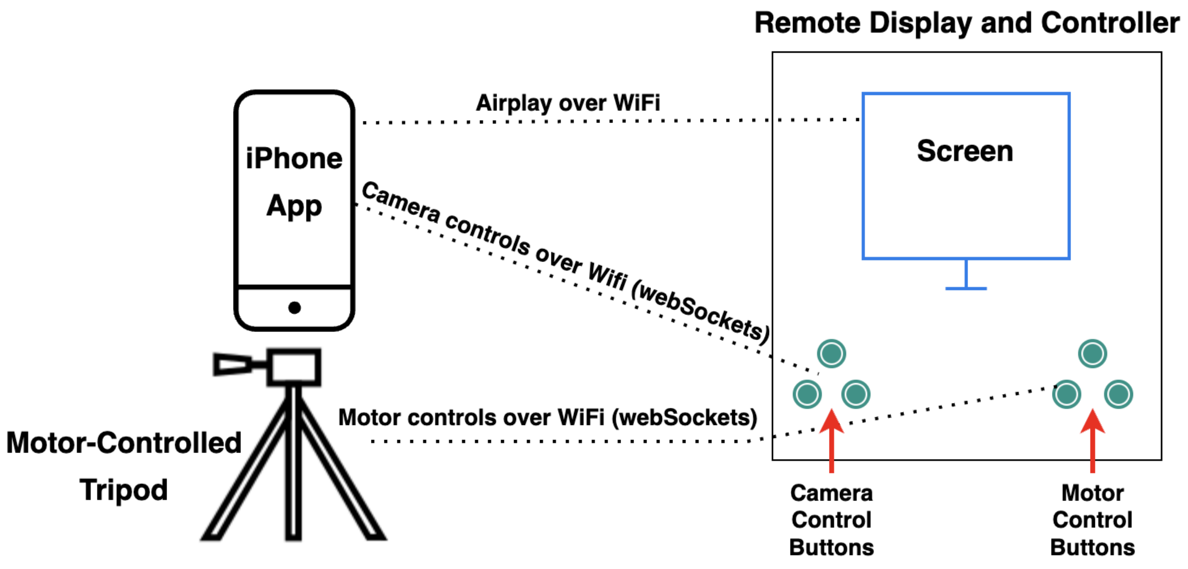
While some motorized tripods exist, they often have limited functionality, primarily offering simple pan-and-tilt adjustments without real-time feedback. Most lack an integrated system to preview the camera’s live feed, requiring users to make adjustments blindly or rely on trial and error. Furthermore, existing solutions do not offer automatic subject tracking, meaning users must manually control the tripod’s movements to keep themselves or their subjects centered in the frame. This gap in functionality creates a need for a more advanced, user-friendly solution that allows for remote tripod control, real-time framing adjustments, and automatic subject tracking, ultimately enhancing the convenience and precision of capturing high-quality photos and videos.

1.2 Solution

Our project introduces a Smart Tripod that enhances traditional tripods by incorporating motorized adjustments, wireless control, and automatic subject tracking. Unlike standard tripods that require manual repositioning, our system allows users to seamlessly adjust their smartphone camera’s orientation using an external remote. This remote features an integrated display that mirrors the smartphone’s screen, providing real-time feedback on framing and composition. In addition to live preview, the remote includes built-in controls for zooming, capturing photos, and recording videos, all seamlessly integrated through a dedicated smartphone app. By eliminating the guesswork involved in setting up a shot, users can make precise, remote adjustments with ease.

For users capturing personal videos or dynamic scenes, the Smart Tripod includes an advanced tracking mode that automatically adjusts the smartphone’s orientation to keep the subject centered in the frame. This ensures smooth and professional-looking footage without the need for constant manual corrections. By combining motorized control, live screen sharing, app-integrated camera controls, and intelligent tracking, our solution offers a seamless, user-friendly experience for capturing high-quality photos and videos with minimal effort.

1.3 Visual Aid


Remote Display and Controller
Airplay over WiFi
iPhone App
Screen
Camera controls over Wifi (webSockets)
Motor controls over WiFi (webSockets)
Motor-Controlled Tripod
Camera Control Buttons
Motor Control Buttons

1.4 High-level requirements list

1.4.1 Motor Accuracy and Responsiveness

The Smart Tripod's motorized control system must provide fast and precise adjustments to ensure smooth framing and subject tracking. Specifically, the motors should respond to user inputs and automated tracking commands for azimuth and zenith adjustments within 250 milliseconds, with a positioning accuracy of ±2°. Given the use of stepper motors, we anticipate potential sources of delay from signal transmission, microcontroller processing, and motor inertia. To verify compliance, we will log and analyze motor response times using timestamped command executions and track angular accuracy using the iPhone's built in gyroscope and external motion capture.

1.4.2 iPhone Camera Action and Responsiveness

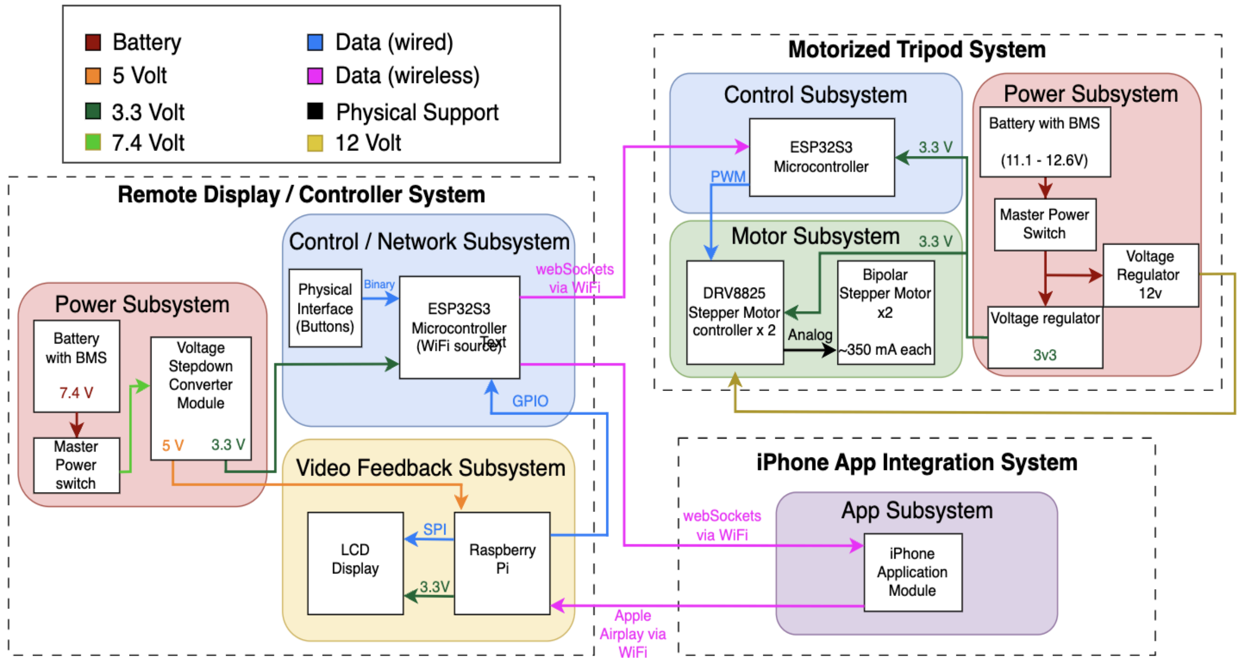
The system must provide real-time remote camera operation over WiFi, allowing users to capture photos, record videos, and adjust zoom with minimal delay. Camera actions triggered from the external remote interface should execute within 500 milliseconds via WebSockets communication to ensure a smooth user experience. Factors that may affect performance include network congestion, WebSocket transmission latency, and iPhone processing time. We will evaluate this requirement by measuring round-trip command execution time from the moment a user triggers an action on the remote to the confirmation of execution on the iPhone, using code-based timestamp logging and network performance analysis tools.

1.4.3 Airplay and Tracking Responsiveness

The Smart Tripod must provide low-latency, high-frame-rate live streaming from the iPhone to the external display via AirPlay. The video feed should maintain at least 24 FPS with <1 second of latency while streaming through a Raspberry Pi. Additionally, the system must perform subject detection via OpenCV and send corrective tracking commands to the motors within 500 milliseconds of receiving the video feed. Challenges include AirPlay transmission delays, Raspberry Pi processing constraints, and real-time OpenCV computation overhead. We will assess system performance by logging frame rates, transmission latencies, and processing times using code-based timestamp logging.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview and Requirements

2.2.1 Remote Display / Controller System

2.2.1.1 Power Subsystem

<u>Purpose and Interactions:</u>

The power subsystem of the remote display / controller system is responsible for the maintaining power input to the control/network subsystem, and the video feedback subsystem. It is only intended to power the electronics onboard the remote controller. The power subsystem will consist of a battery with an internal BMS capable of supplying proper current for the two step downs. These two step downs will be from 7.4v to 5v for the Video Feedback subsystem and 7.4v to 3.3v for the Control/Network subsystem. The power subsystem will also be capable of being charged over an onboard micro usb connector and will have a master power switch to shut off current flow to the other subsystems.

Requirements:

- The power subsystem should be capable of supplying 800mA to the control system at 3.3 V $\pm$ 100mV from the step down converter to ensure safe operation of the ESP32S3 and its peripherals. It should be able to supply this current and voltage irrespective of voltage drops from the battery pack.
- The power subsystem should be capable of supplying 3.5 A to the video feedback system at 5 V $\pm$ 100mV from the step down converter to ensure safe operation of the Raspberry Pi and its peripherals. It should be able to supply this current and voltage irrespective of voltage drops from the battery pack.
- The battery pack should be capable of supplying a maximum of 4.5 A to account for power transfers over the step down along with heat losses. To achieve this the battery must at minimum be a 7.4V 2250 mAh 2c, to meet power and lifetime requirements.
- The master power switch should isolate the battery from the load. When powered on, it should have a maximum on-state resistance of 30±20 mΩ to ensure low power consumption and a small voltage drop across the power switch..

2.2.1.2 Control / Network Subsystem

Purpose and Interactions:

The ESP32-S3 serves as the central controller for the tripod's motorized adjustments and iPhone camera control. The microcontroller will offer both manual and automated control. It features physical buttons for direct control of azimuth (pan) and zenith (tilt) movement, as well as dedicated buttons for zoom, photo capture, and video recording. A switch allows users to toggle between manual mode and subject tracking mode for greater flexibility.

For automated operation, the ESP32-S3 receives subject tracking data from the Raspberry Pi via GPIO, dynamically adjusting the tripod's position using stepper motors. It also communicates over WiFi via WebSockets, enabling remote control of both the motors and iPhone camera functions. To ensure seamless connectivity, the ESP32-S3 establishes a dedicated 2.4GHz WiFi network for system communication. This WiFi network will maintain the Airplay and webSocket connections used throughout all of our subsystems. The remote control interface integrates a custom PCB and a power management system for efficient operation.

Requirements:

- Motor Button Response and Tracking Control Latency – The ESP32-S3 must process manual button inputs and subject tracking data and send stepper motor commands with

≤125 ms latency, allowing ample time for motors to receive and react to commands within the 250ms high level requirement.

- Camera Button Response Latency – The ESP32-S3 must process manual button inputs for camera control and send iPhone camera control commands with ≤250 ms latency, allowing sample time for the iPhone to receive and react to commands within the 500ms high level requirement.
- Network Throughput Capacity – The ESP32-S3's dedicated WiFi network must support simultaneous motor control, camera commands, and tracking data transmission without exceeding 80% of available bandwidth to prevent congestion.
- Network Stability – The ESP32-S3 must maintain a stable connection with ≤5% packet loss, ensuring reliable data transmission across all system components.
- Power Consumption – The ESP32-S3 must operate a ≤0.5W power budget to ensure efficiency in portable use and to prevent excessive overheating.

2.2.1.3 Video Feedback Subsystem

Purpose and Interactions:

The Video Feedback Subsystem is responsible for collecting and processing the iPhone's video feed. It consists of a Raspberry Pi 4 and a Waveshare 2.4-inch SPI LCD screen for real-time monitoring. The Raspberry Pi runs RPiPlay to wirelessly receive the iPhone's camera feed via AirPlay, enabling smooth video streaming.

Using OpenCV, the Raspberry Pi processes the video stream to detect and track the subject's position. It then transmits tracking data to the ESP32-S3 via 3.3V GPIO communication, ensuring precise position updates. The ESP32-S3 interprets this data and dynamically adjusts the tripod's orientation to keep the subject centered in the frame. Operating in a continuous feedback loop, the system ensures real-time tracking and seamless camera adjustments.

Requirements:

- AirPlay Streaming Latency – The iPhone's screen must stream to the Raspberry Pi with ≤1s latency at ≥24 FPS for real-time monitoring.
- OpenCV Processing Speed – The Raspberry Pi must process subject tracking data and send tracking commands with ≤500 ms latency to ensure smooth camera adjustments.
- Power Consumption – The Raspberry Pi and Waveshare LCD must operate within a ≤6.4W(Raspberry Pi 4 full stress power consumption) power budget to ensure efficiency in portable use and to prevent excessive overheating.

2.2.2 Motorized Tripod System

2.2.2.1 Power Subsystem

Purpose and Interactions:

The power subsystem of the tripod system is responsible for the maintaining power input to the tripod control subsystem, and the motor subsystem. It is only intended to power the tripod system and not the remote control. The power subsystem will consist of a battery with an internal BMS capable of supplying proper current for the motors, the step down, and the voltage regulation. The step down will be from 12v to 3.3v to power the ESP32S3 onboard the control system and supply a logic level reference voltage to the stepper motor controller. The power system will be chargeable through the battery pack connector, and will also contain a master power switch to ensure the battery is separated from the load when not in use.

Requirements:

- The power subsystem should be capable of supplying 800mA to the control system at 3.3 V ± 100mV from the step down converter to ensure safe operation of the ESP32S3 and its peripherals. It should be able to supply this current and voltage irrespective of voltage drops from the battery pack.
- The voltage regulator should be capable of supply 1A of current at 12 V ± 200 mV, irrespective of the input voltage which could be anywhere from 11.1 - 12.6 V.
- The battery pack should be capable of supplying a maximum of 2A to account for power transfers over the step down along with efficiency losses.. To achieve this the battery must at minimum be a 12V 2000 mAh 1c, to meet power and lifetime requirements.
- The master power switch should isolate the battery from the load. When powered on, it should have a maximum on-state resistance of 50±20 mΩ to ensure low power consumption and a small voltage drop across the switch.

2.2.2.2 Control Subsystem

Purpose and interactions:

The control subsystem of the motorized tripod system will consist of an ESP32S3. It will interface with the ESP32S3 on the control/network subsystem of the remote control. The control subsystem of the tripod will communicate with the subsystem of the remote, to ensure the tripod is oriented properly. To orient the tripod properly, the control subsystem will interface with the motor subsystem to translate azimuth and zenith angle instructions from the controller. It will receive power from the power subsystem of the tripod.

Requirements:

- Motor Button Response and Tracking Control Latency – The ESP32-S3 must send stepper motor commands after receiving   with ≤125 ms latency, allowing accurate positioning with relatively small delay.
- Network Stability – The ESP32-S3 must maintain a stable connection with ≤5% packet loss, ensuring reliable data transmission between the controller and the tripod.
- Power Consumption – The ESP32-S3 must operate a ≤0.5W power budget to ensure efficiency in portable use and to prevent excessive overheating.

2.2.2.3 Motor Subsystem

Purpose and interactions:

The motor subsystem is the physical interface between the tripod angling system and the control system. It is used to accurately position the zenith and azimuth angles of the phone, to allow for tracking or direction control based on user input. The motor subsystem will consist of two L298 IC driver chips and two bipolar stepper motors. The stepper motors will allow for fine control over position. The L298 IC drivers will interface with the tripod control system, to translate position commands to current in the coils of the stepper motor. The motor subsystem will receive both 3.3v and 12v power input from the power subsystem.

Requirements:

- The motor and controller should draw ≤ 12W of power at any given moment, to ensure safe power consumption and decent battery lifetime of the tripod.
- The motor subsystem should be capable of stepping in ≤ 2° increments. This will create fine control over position to accurately position the tripod's camera holder.

2.2.3 iPhone App Integration System

2.2.3.1 App Subsystem

Purpose and Interactions:

A custom app will use WebSockets to receive commands from the ESP32-S3 over WiFi, allowing control of iPhone camera functions via AVFoundation, such as starting/stopping video recording, capturing photos, and adjusting zoom. The live camera feed will be transmitted via AirPlay for real-time viewing on the external display. The app will also provide feedback regarding connection issues experienced during use to ensure a better user experience.

Requirements:

- Camera Command Execution Latency – The app must execute camera control commands (e.g., photo capture, video recording, zoom adjustments) within 250 ms after receiving them via WebSockets over WiFi, allowing ample time for the ESP32-S3 to send commands to adhere to the 500 ms latency high level requirement.
- Network Throughput and Stability – The app/iPhone must maintain a stable connection with the ESP32S3 via WebSockets, with ≤5% packet loss and ≥1 Mbps bandwidth to support real-time control commands and live video streaming.
- Video Streaming Quality – The app should support video streaming via AirPlay at ≥24 FPS with ≤1 second latency, ensuring that the live camera feed is smooth and responsive when displayed on the external monitor.
- Power Consumption – The iPhone application and Airplay action must operate within a ≤3W power budget to ensure efficiency in portable use and to prevent excessive overheating. Xcode's energy log software will be utilized to test this requirement.

2.3 Tolerance Analysis

Since our system relies on fast and precise communication between the iPhone, remote display/controller, and motorized tripod, it is crucial to minimize overall system delay. To ensure smooth operation, we must analyze and optimize response times at every stage, including command transmission, processing, and motor adjustments. Reducing latency in automatic mode is especially critical for real-time tracking, ensuring the tripod can continuously adjust to keep the subject centered without noticeable lag.

Seamless communication between devices is essential for ensuring the overall responsiveness of our system. Given the importance of minimizing delay, we must identify and optimize any sources of latency that could impact performance. This includes transmission delays, processing times, and synchronization across all components. To effectively analyze these potential bottlenecks, we categorize them into three critical areas:

1. WiFi WebSockets Delay between ESP32-S3 to iPhone / Motorized Tripod.
2. AirPlay Streaming Delay from iPhone to Raspberry Pi.
3. OpenCV Processing Delay and its impact on tracking responsiveness.

In all areas the intention is to utilize delay equations to be able to estimate and quantify these potential delays.

2.3.1 WiFi Websockets Delay (ESP32-S3 to iPhone / Motorized Tripod)

Our plan is to have the ESP32 microcontroller send WebSockets commands over WiFi to the iPhone and the ESP32 microcontroller on the tripod.

In any network, the delay is made up of multiple components that sum up to the total delay between sending and receiving between two different devices. In sending WebSockets commands the main delay components are:

- **Processing Delay**: Time for the microcontroller to process and send a command
- **Queueing Delay**: time waiting in the network for transmission
- **Transmission Delay**: time it takes to transfer each bit onto the network
- **Propagation Delay**: time it takes for signal to travel over the WiFi channel

Dtot = Dproc + Dq + Dt+ Dp

Through our research thus far, we've been able to find that on average the **Processing delay** of the ESP32 is roughly **~2.5ms**. The **Queuing delay** for a lightly loaded wifi network is roughly **>1ms**.

Transmission Delay

Transmission depends highly on the size of the packets needed to be sent as well as the wifi speed. A WebSockets command is 256 bytes or 2048 bits. From research we've found that in the best circumstances the ESP32 is able to transmit at roughly 30Mbps.

Transmission Delay can then be calculated using:

Dt = L / R, where L = length of packet (bits) and R = Link bandwidth (bps)

Dt = 2048 / (30 * 10^6) = 0.00006826666 = **0.0682 ms**

Propagation Delay

This delay as mentioned above refers to the time it takes for the signal to travel over the WiFi channel. It is as simple as:

Dp = d / s, where d = distance and s = speed of propagation.

We will for now calculate the propagation delay for d = 5 meters , which should be the average distance that this tripod will be used from.

For wifi, the signal propagates roughly the speed of light (~3*10^8 m/s).

So in terms of our calculations Dp = 5 / (3*10^8) = **16.67 nanoseconds.** This is essentially negligible for our system.

Total Delay for WebSocket Commands

With our calculations thus far, we can now calculate the total delay we might experience from each WebSocket command being sent to the app.

Dt = Dproc + Dq + Dt + Dp

Dt = 2.5 ms + 1 ms + 0.0682 ms + 1.6 ns = **3.5862 ms**

This value refers to an estimated value of the delay that will incur from ESP32 when sending and receiving commands.

ESP32 to Motor

WebSocket Commands have a huge role in sending the necessary data to the motors for adjustment. The calculation above is crucial as that is the amount of time it takes for WebSocket commands to be sent and processed.

We've been able to estimate the time it'll take for a stepper motor to make small adjustments. In our research we've found that in typical motor applications, stepper motors require around 50-150 ms to complete small adjustments. This means that **100ms** would be a reasonable estimate for quantification purposes.

With the addition of having to send the WebSockets command and processing first we can find the total delay for the motors actually moving by summing up these two values.

Dmotor = 3.5862 + 100 = 103.586 ms

2.3.2 AirPlay Streaming Delay from iPhone to Raspberry Pi

The other area where we want to examine performance is how the AirPlay streaming from our iPhone to the Raspberry Pi will work. The AirPlay streaming latency introduces four main components:

- **Encoding delay (Dencode): Time it takes to send the stream**
- **Decoding delay (Ddecode): Time it takes to decompress video**
- **Rendering delay (Drender): Time it takes to display the frame**
- **Transmission delay (Dt): Time it takes to send the stream**

Equation: Dairplay = Dencode + Ddecode + Render + Dt

<u>Encoding Delay</u>

The iPhone typically compresses videos into H.264 before sending the videos over AirPlay. We found that the typical encoding times for H.264 at 720p/30FPS can range from 50-150ms. These times depend on the video resolution, the iPhone's hardware acceleration, and as well as the Codec used, H.264 should be efficient enough.

Apple's hardware encoder has the ability to encode a 720p video in **~100ms**.

<u>Transmission Delay</u>

When the video is encoded, it will have to be transmitted over WiFi. With the assumption of a 10 Mbps throughput from the ESP32, the transmission time for a 720p frame (~1.5Mbits) would be:

1.5/10 = 0.15 sec = **15ms.**

<u>Decoding Delay</u>

Once the video has been transmitted to the Raspberry Pi, the Pi must now utilize its hardware decoder to decompress the video stream. We've found that this typically takes around 30-60ms. We will choose a value closer to 60ms in order to account for potentially buffering and synchronization issues.

Ddecode = **50ms**

<u>Rending Delay</u>

Once decoded, we must then render frame-by-frame on the display. For quantification purposes, we find that a 60Hz display refreshes every 16.7ms, so rendering will typically take one frame cycle roughly **20ms**.

Total AirPlay Latency

Our total AirPlay Latency estimate will be the sum of all the main components in our delay calculations.

Dairplay = Dencode + Ddecode + Render + Dt

Dairplay = 100 + 15 + 50 + 20 = **185ms**

A value of 185ms is reasonable as our research shows that Apple TV's AirPlay latency is reported to be around 150-200 ms for our goal resolution and frame rate. We also take into account the overhead that comes from the Raspberry Pi, so all in all this would be very reasonable for our intended purpose.

2.3.3 OpenCV Processing Delay and Impact on Tracking Responsiveness

This portion of the latency calculations is the latency regarding what will be our OpenCV algorithms that will be processed once the Raspberry Pi receives video from iPhone AirPlay. OpenCV is crucial for the ability to detect and track objects in real time. With this, it introduces three main components:

- **Capture Delay (Dcapture): Frame capture time from AirPlay video input**
- **Processing Delay (Dprocess): Time it takes for OpenCV to process and track objects**
- **Transmission Delay (Dt): Time it takes to transmit tracking data via WebSockets**

Equation:
Dopen_cv = Dcapture + Dprocess + Dsend

Frame Capture Delay
This essentially just takes into account the kind of delay we'll perceive depending on the chosen frame rate for our real-time video. As stated in our requirements, we want the video to be at least output at >24fps.

This essentially means that the time for each frame would be:
Dcapture = 1 / 24 = 0.042 seconds = **42ms**

OpenCV Processing Delay
OpenCV processing delay relies heavily on the tracking algorithm of our choice. In our research we've found that there are many choices for us to choose from when developing our tracking

algorithm. Our research shows that some of the fastest can process **~100 to 300 ms**. This is reasonable for now, but a lot of factors definitely affect it such as the complexity of calculations and how we'll handle frame resolution and processing.

A choice of Dproc = **200ms** should be sufficient enough to at least give us some idea to quantify the OpenCV delay.

Tracking Data Transmission
There is an extra delay when sending the tracking commands through the GPIO pins between the Raspberry pi and the ESP32.

We can calculate this delay by taking the length of the wired connection (~30mm) and dividing by the speed of electricity through copper (~3*10^8m/s).

Dsend = .03 / (3*10^8) = **0.1ns**

This value is small, and can be neglected.

There is an additional delay due to the reading of the GPIO pin state, and for an ESP32 this takes typically between 0.1-1ms, which again is negligible for our system.

Total OpenCV Processing Delay

With all our previous calculations, we can now quantify a reasonable estimate for the delay we can expect from our OpenCV algorithm when creating motor data from our tracking and processing of the AirPlay input.

Dopen_cv = Dcapture + Dprocess
Dopen_cv = 42 + 200 = **242 ms**

This is a reasonable estimate for our OpenCV since it heavily relies on our tracking algorithm. Many factors go into reducing this number and we'll have to take this into account when developing our OpenCV tracking algorithm for our project.

2.3.4 Total Delay of System and Conclusion

Total Estimated Delay of System
With all necessary calculations and delay estimates quantified we can sum all values up to get an estimate for the total delay of the entire system in real-time.

For further analysis we have decided to calculate the Worst-Case Total Latency for the system. We are choosing to add 100ms to account for network queuing with the ESP32. This means that our final equation becomes:

Dtotal = Dairplay + Dopencv + Dweb_socket + Dnetwork + Dmotor

Dtotal = 3.5862 + 103.5862 + 185 + 242 + 100 = **634.172ms**

This remains well within our target total round-trip time of under 1.75 seconds (1 second for AirPlay transmission, 500 ms for OpenCV processing and tracking commands, and 250 ms for motor response). When the tripod is operating in manual mode, the delay should be far smaller as there will not be an OpenCV processing element and Airplay latency contributing to the total delay. Additionally, we can explore using a more efficient codec for encoding the stream before sending it through AirPlay to further reduce latency. These estimates provide a solid expectation for overall system delay as we begin developing the network communication between our core components.

These calculations also give us valuable insight into optimizing our OpenCV algorithm. Our goal is to significantly reduce processing time through algorithmic improvements and optimizations. The 1.75-second upper bound is based on the necessity of aligning frame updates with the display's refresh cycle—if our timing is off, the stream may not display correctly, resulting in inaccurate feedback for the user, and unresponsive automatic tracking.

3. Ethics and Safety

Our project raises several ethical concerns that can be categorized into four key areas: Privacy and Surveillance, Bias in Computer Vision Tracking, Transparency and Honesty, and Accessibility and Inclusivity.

3.1 Privacy and Surveillance

Privacy is a primary concern due to the Smart Tripod's use of object tracking, remote control functionality, and live camera feeds. These features inherently involve wireless communication, screen mirroring, and data transmission, which could pose risks if not properly managed. To align with IEEE Code of Ethics I.1, which emphasizes the responsible handling of user data and privacy protection, we will ensure that users are fully aware of what data is being collected at all times. Clear visual indicators will notify users when tracking or remote access features are active, preventing unauthorized or unnoticed usage.

3.2 Bias in Computer Vision Tracking

To ensure fair and unbiased tracking, the object detection system must be trained on diverse datasets to prevent any unintended biases that could cause the algorithm to favor or exclude certain individuals. This aligns with IEEE Code of Ethics II, which calls for fairness and respect in technology development. By testing the system with a wide range of skin tones, clothing variations, and lighting conditions, we will work to eliminate biases and ensure accurate tracking for all users.

3.3 Transparency and Honesty

Maintaining transparency and honesty throughout the development process is essential. Users must have confidence that the Smart Tripod operates as advertised and that its limitations and risks are communicated clearly. To adhere to IEEE Code of Ethics I.3, which emphasizes honesty in engineering practices, we will provide detailed documentation of the system’s capabilities and limitations. This includes publishing clear user guidelines, performance expectations, and any potential risks associated with the product.

3.4 Accessibility and Inclusivity

The Smart Tripod should be intuitive and accessible to all users, regardless of technical expertise. In accordance with ACM Principle 1.4, which promotes fairness and inclusivity in technology, we will design the interface to be user-friendly, with clear controls and straightforward setup. Additionally, users will have full control over recording and tracking functions, ensuring that the system does not unintentionally capture footage or track subjects without explicit consent.

By addressing these ethical considerations proactively, we aim to develop a secure, fair, and transparent product that respects user privacy while enhancing the photography and videography experience.