# Vein Detection

**Enhancing Precision, Reducing Discomfort in Healthcare**

Project Report


220009H Abeysinghe G. A. I. N. M

220029T Ananthakumar.T

220096T Dayananthan.T

Department of Electronics and Telecommunication Engineering

University of Moratuwa, Sri Lanka


August 22, 2024

# Content

# ABSTRACT

Vein detection technology makes it easier to find veins, which is particularly important for procedures like blood draws and IV insertions. For small children, people with darker skin, and the elderly, locating veins can be challenging due to varying skin types and vein visibility. This system uses infrared light and advanced image processing to clearly display veins on a screen, helping healthcare providers quickly and accurately find veins. This technology not only improves the precision of medical procedures but also reduces discomfort and stress for patients, making it a valuable tool in providing effective and compassionate healthcare.

## 1. Introduction

In the healthcare sector, accurate and efficient vein detection is crucial. . Traditional vein detection systems can be expensive and often require specialized equipment that is not always accessible in every healthcare setting. Our project addresses these challenges by developing a cost-effective, smart vein detection system that provides a clear and accurate visualization of veins. This device is designed to be accessible via a web-based interface. By offering a budget-friendly solution that combines with ease of use, we aim to improve the efficiency and accuracy of medical procedures while making vein detection more accessible to a broader range of healthcare facilities.

## 2. Background Research

The background research for developing the vein detection system covered several key areas, including hardware components, imaging techniques, and programming languages.The following sections provide an overview of the components and technologies that are integral to the project, ensuring the system is both functional and user-friendly.

*ESP WROOM  S3 U1 Microcontroller*

The ESP WROOM S3 U1 microcontroller is strategically chosen for the vein detection project due to its advanced processing capabilities and substantial memory resources, making it particularly well-suited for image processing tasks. Powered by the ESP32-S3 SoC, this microcontroller features a dual-core Xtensa LX7 processor operating at 240MHz, delivering the high-performance computational power necessary for real-time image analysis. With support for up to 16 MB of PSRAM, the ESP WROOM S3 U1 offers significant memory capacity, enabling efficient handling of complex image data critical for

Accurate vein detection. Additionally, the integrated Wi-Fi and Bluetooth functionalities facilitate seamless communication of processed data, further solidifying the ESP WROOM S3 U1 as an optimal choice for applications requiring precision and reliability in image-based projects like vein detection compared to other ESP chips

*ESP CAM*

For the vein detection project, the ESP32-CAM module was selected due to its flexibility and adaptability, particularly in scenarios where a NoIR (No Infrared) camera is essential. While Raspberry Pi cameras with NoIR capability are available, they are not compatible with the ESP32 microcontroller, which is a core component of our project. To address this limitation, we opted to use the ESP32-CAM module and modify it by removing the infrared (IR) filter. This modification allows the camera to capture the infrared wavelengths necessary for effective vein detection.

*TFT 1.8' LCD display*

The TFT 1.8" LCD display was chosen for the vein detection project due to its efficient SPI communication, which offers fast data transfer with minimal latency, making it ideal for live streaming applications. The compact size of the display contributes significantly to reducing the overall footprint of the product, aligning with the project's goal of creating a portable and space-efficient device. Additionally, the cost-effectiveness of the TFT 1.8" LCD display makes it a practical choice, ensuring that the project remains budget-friendly without compromising on performance or quality.

*LED Array and IR LED*

The design incorporates a circular LED array with IR LEDs strategically placed around the camera, which is positioned at the center. This configuration ensures optimal capture of the reflected infrared light, enhancing the efficacy of image acquisition for vein detection. The IR LEDs operate at a wavelength of 850 nm, which is highly suitable for vein detection due to its ability to penetrate the skin and highlight veins effectively. To ensure the safety and longevity of the LEDs, suitable resistors have been selected to regulate the current, preventing overheating and ensuring consistent performance.

*Lithium battery and Charging Module USB Booster*

We required a 5V to 8.5V battery to power our PCB, but only 3.7V batteries were available. To meet the voltage requirement, we combined two 3.7V lithium batteries in series. Additionally, since we're using lithium batteries, we included a USB port for recharging the PCB to ensure convenient and reliable power management.

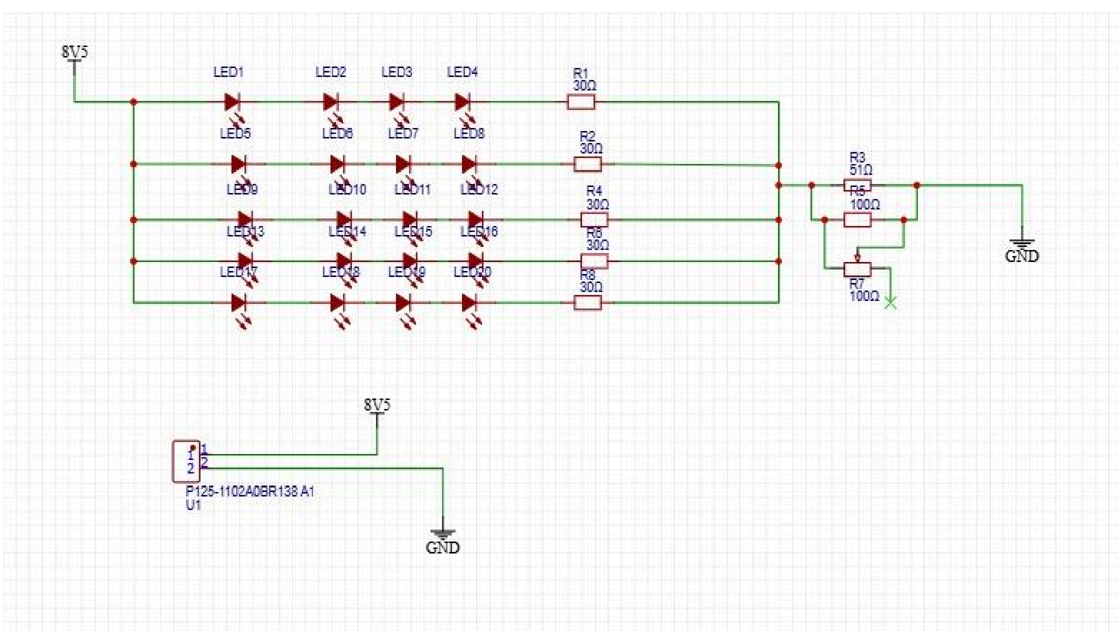
# 3. Project Description

## 3.1 Circuit Design

In order to develop the vein detection system, we utilized several key schematics to achieve the desired functionality. The primary components used in the circuit include the ESP WROOM S3 U1 microcontroller, a circular IR LED array, potentiometers, resistors, and a camera module. The ESP WROOM S3 U1 managing communication tasks with display. The circular IR LED array, designed with carefully selected resistors and a potentiometer, ensures optimal illumination for vein visualization by providing controlled infrared light around the camera module. The following sections provide an overview of each circuit used in this design,

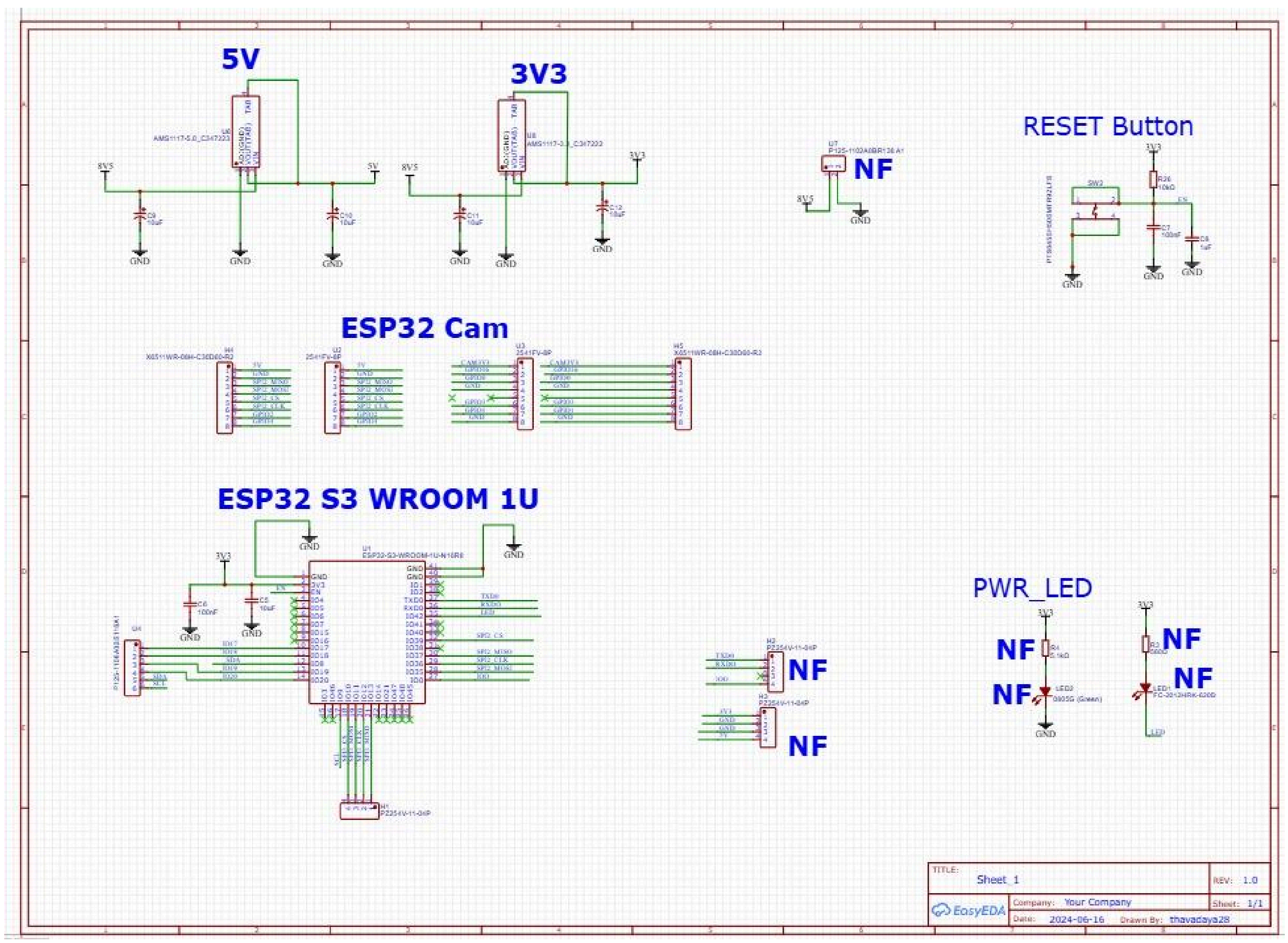
*IR Led Array*

The IR LED array schematic was custom-designed based on our specific requirements for the vein detection system. The design process involved manually calculating the resistor values to ensure the safety and longevity of the IR LEDs, preventing overheating and ensuring consistent performance. Additionally, the distance between each LED was carefully calculated to optimize the coverage and intensity of the infrared light, enhancing the efficiency of image capture. By strategically positioning the LEDs in a circular array around the camera, the design maximizes the reflection of infrared light, which is crucial for accurate vein visualization. This custom schematic effectively integrates the IR LED array into the overall system, ensuring high performance and reliability.



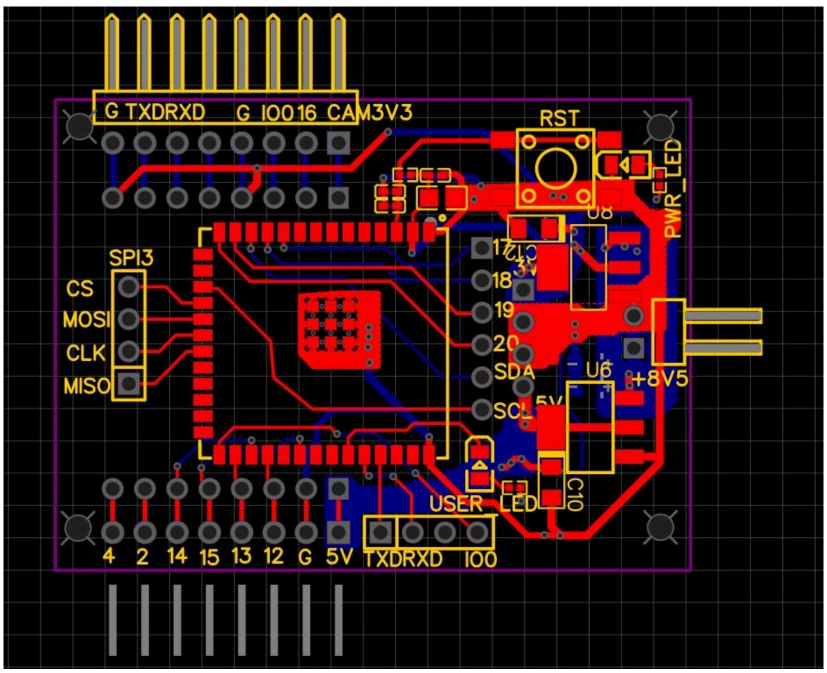
*ESP WROOM S3 U1*

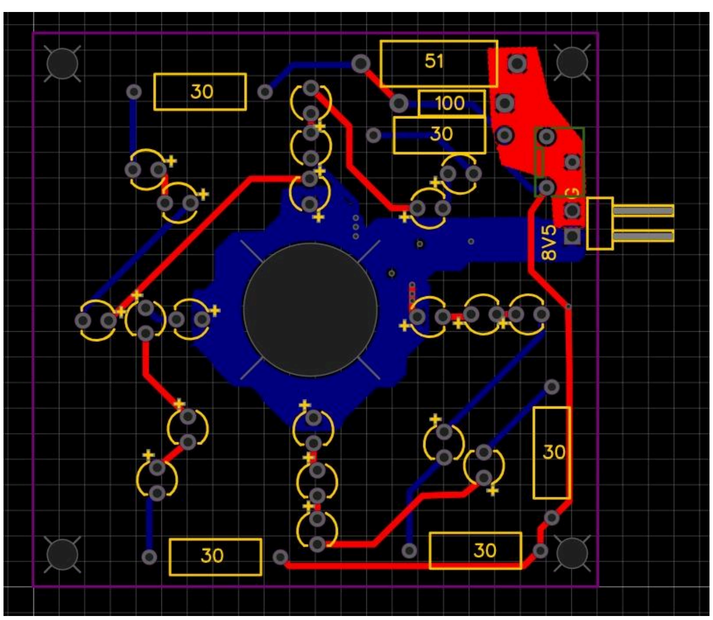
The circuit design began by incorporating the ESP WROOM S3 U1, a powerful and versatile Wi-Fi and Bluetooth-enabled microcontroller, into the system. To ensure stable and efficient performance, we used the ESP WROOM S3 U1 reference circuit provided by Espressif's official documentation as the foundation. Necessary modifications were made to tailor the reference design to the specific needs of our vein detection project, optimizing the circuit for image processing and real-time data communication while maintaining reliability and efficiency.



### 3.2 PCB Design

The Vein Detection circuit has been designed using Altium Designer, enabling industry-standard PCB (Printed Circuit Board) design. In this section, we will explain various aspects of our PCB layout, including the placement of components, trace width, and clearance for critical nets. We will also discuss specific design rules implemented to ensure that the Vein Detection system operates reliably and without faults.



*Component Placement and 3D Models*

In the PCB design process for the Vein Detection system, significant attention was given to the strategic placement of components to optimize performance, minimize noise, facilitate easy soldering, and reduce the overall size of the device. We utilized Altium's manufacturer part search feature to obtain layouts and 3D models for most components, ensuring that selected parts are readily available in the market. Additionally, the SnapEDA website was used to obtain footprints for some components. The 3D models allowed us to conduct comprehensive mechanical checks, ensuring that there were no interferences with the enclosure or other components, thereby simplifying the assembly process.

*Trace Width and Current Considerations*

Trace Width and Current Considerations:
In the design of the Vein Detection system, careful attention was given to trace layout, particularly when designing the circular LED PCB where IR LEDs are positioned in close proximity. For the WROOM PCB, we prioritized proper trace sizing to ensure reliable operation and minimize any potential signal interference. Additionally, we incorporated reset buttons and header pins on both sides of the WROOM PCB to facilitate the mounting of the camera module. This strategic placement and trace design were crucial in optimizing the overall functionality and durability of the system.

*Clearance and Safety Measures*

Electrical safety was a primary concern in the PCB design for the Vein Detection system. To ensure proper operation and safety, we carefully managed clearances, particularly between high-voltage and low-voltage sections. For the camera module, which requires a stable 5V power supply to function correctly, we ensured that the power pins are appropriately designed to deliver the required voltage. This careful design consideration helps prevent operational issues with the camera and enhances the overall safety and reliability of the system.

*Issues with PCB design*

Although we designed our PCB properly there is voltage drops less than 5 in each pin.

*Future Implementations*

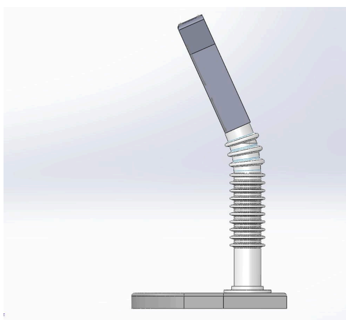
In the future, we plan to enhance the PCB design for the Vein Detection system to prevent unwanted interactions, particularly between traces. We will increase the clearances between traces to improve safety and reliability.

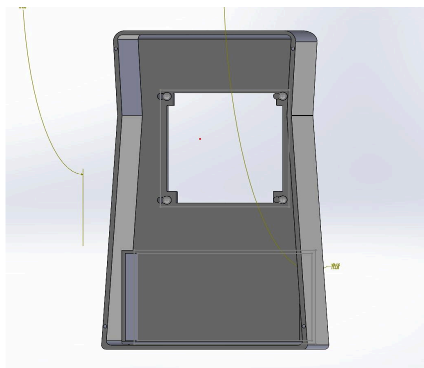
*Manufacturability and JLCPCB Guidelines:*

Throughout the PCB design process, we remained aware of manufacturability requirements of the PCB. We referred to JLCPCB’s manufacturing guidelines to ensure our design complied with their fabrication capabilities and processes. JLCPCB’s .rul file was imported into the "Rules" section of our design software, and necessary changes were made. This proactive approach enabled us to minimize manufacturing errors, reduce production time, and optimize costs

### 3.3 Enclosure Design

The enclosure design is optimized to ensure even stress distribution. Its curvature reduces the required material by minimizing wall thickness through the creation of hoop stress. Additionally, holes are strategically placed at the center to accommodate the camera.





*Technology used* : 3D printing
*Material used* : PLA Bioplastic

The design is a very sleek, compatible and very minimal in size.

*Issues with 3D printing :*

The poles in the enclosure are breaking due to their small diameter, despite the use of high-quality materials. Additionally, alternative mounting solutions, such as standoffs or brackets, could be explored to reduce reliance on the poles for securing the PCB in the upcoming project. This approach will help to improve the overall durability and structural integrity of the design.

### 3.4 Microcontroller Programming

We use Wi-Fi libraries and web server libraries to access the camera through a browser over Wi-Fi. For communication between the WROOM module and the display, we utilize SPI communication with the TFT_eSPI library. To simplify the project, we connect only one Wi-Fi network, ensuring a single IP address for both connection and disconnection. Specifically, the WROOM module handles SPI communication and displays the IP address, while the camera module runs the camera server.

*Future Implementation*

In the future, we plan to use a TFT touch LCD display with an alphanumeric keypad by class defined in Arduino to allow users to input Wi-Fi names and passwords directly on the display. This will enable the system to connect to various Wi-Fi networks, each with its own unique IP address. The WROOM and camera modules will then communicate to share Wi-Fi credentials and IP addresses, facilitating seamless connectivity and operation.

## 4. Non-technical issues

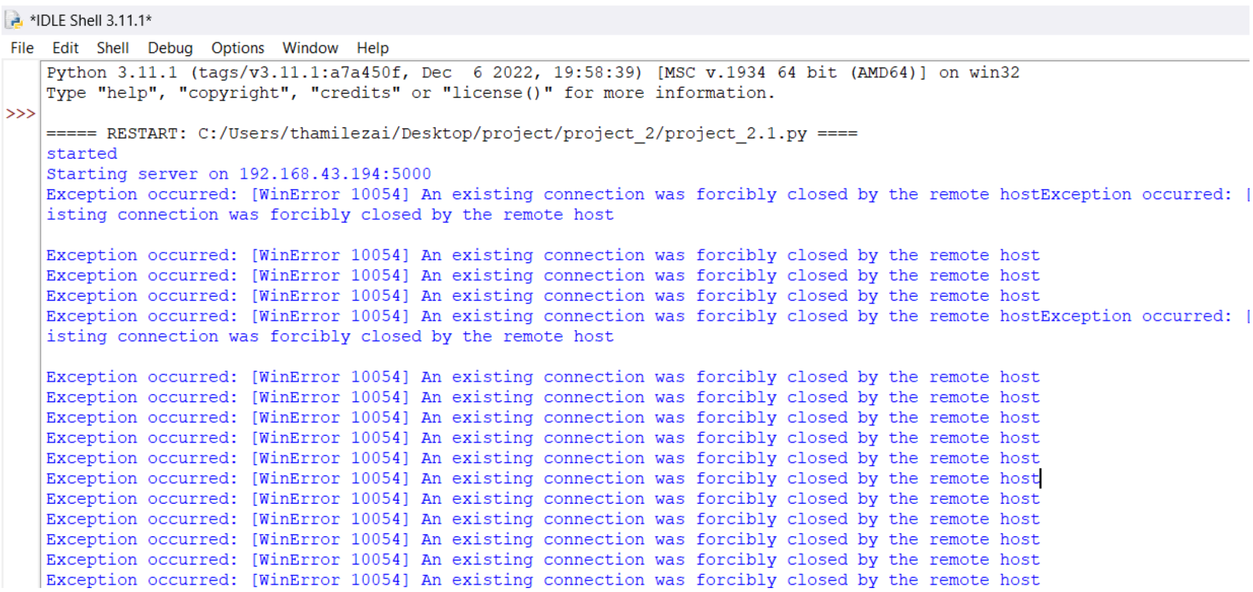
We faced unexpected costs because we had to buy components from China, adding $70 in shipping fees to our budget. Additionally, the TFT display was out of stock in Sri Lanka, which also required international shipping. As this is our first complete project, we weren't prepared for these issues. For future projects, we will research suppliers more thoroughly, budget for unforeseen costs, seek local alternatives, plan logistics more carefully, and discuss cost-sharing arrangements with partners or clients to prevent similar problems.

## 5. Our progress and Limitations

**1. Initial Idea: Live Stream Image Processing with OpenCV**

- We aimed to capture live stream images using the ESP32-CAM and send them via Wi-Fi to a system running OpenCV for advanced image processing tasks, such as edge detection and noise removal.

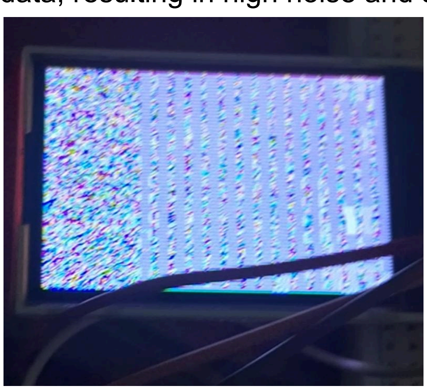
- The processed image was to be sent back to the WROOM chip, which, equipped with PSRAM, would then buffer and display the image on a TFT display through SPI communication.
- However, this approach encountered network termination errors with the OpenCV code, leading us to abandon this plan after unsuccessful implementation attempts.

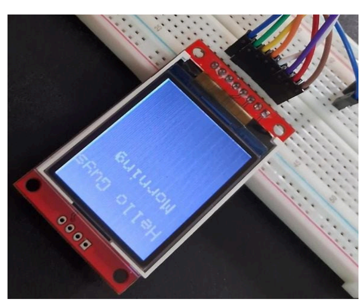


```
*IDLE Shell 3.11.1*
File  Edit  Shell  Debug  Options  Window  Help
Python 3.11.1 (tags/v3.11.1:a7a450f, Dec  6 2022, 19:58:39) [MSC v.1934 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
===== RESTART: C:/Users/thamilezai/Desktop/project/project_2/project_2.1.py ====
started
Starting server on 192.168.43.194:5000
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote hostException occurred: |
isting connection was forcibly closed by the remote host

Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote hostException occurred: |
isting connection was forcibly closed by the remote host

Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
Exception occurred: [WinError 10054] An existing connection was forcibly closed by the remote host
```

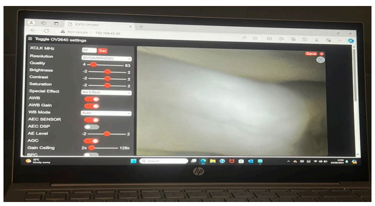
**2. Alternative Approach: Simplified Image Processing with Arduino IDE**

- We considered removing the OpenCV component and opted to capture images with the ESP32-CAM, apply basic noise removal using Arduino IDE, and then send the processed image to the TFT display via SPI communication.
- Unfortunately, the TFT display faced hardware limitations that prevented it from effectively displaying live-streamed images; it could handle text and graphics but struggled with image data, resulting in high noise and stuck frames.





**3. Final Solution: Web Browser Display via Camera Server**
- Given the issues with the TFT display, we shifted to displaying the captured image in a web browser using the camera server feature of the ESP32-CAM, utilizing web server and Wi-Fi libraries.
- By typing the IP address into a browser, users can view the image, and the WROOM chip displays this IP address on the TFT screen, which remains constant for a single Wi-Fi Connection.



Camera Web Server Vein

**4. Future Considerations: Mobile Accessibility**
- After discussions with medical professionals, we learned that mobile accessibility is preferred for future projects. This feedback has led us to focus on solutions that are more mobile-friendly, aligning with user preferences and improving overall usability.

Each step reflects a thoughtful progression, responding to technical challenges and user feedback, leading to a more robust and user-centric solution.

## 6.Task Allocation

| Name | Task Allocation |
|---|---|
| Abeysinghe G. A. I. N. M | Product Enclosure Design with SolidWorks.<br>Testing and Troubleshooting |
| Ananthakumar.T | Program Development.<br>Testing and Troubleshooting |
| Dayananthan.T | PCB Designing using Altium and<br>Product Soldering and Assembling the product.<br>Testing and Troubleshooting |

## 7. Conclusion and Future Work

Our project initially focused on developing a vein detection system, overcoming challenges related to image capture and processing. Despite technical and hardware limitations, we made significant progress in integrating components like the ESP32-CAM and TFT display. However, we faced issues with live image streaming and processing due to hardware constraints and network termination errors, which led us to pivot our approach multiple times.

Looking ahead, our future plan is to implement a 2.8" TFT touch display with an alphanumeric keypad, enabling users to input their network name and password directly on the device. This will allow for dynamic Wi-Fi connectivity, with communication between the WROOM and CAM modules to update and display variable IP addresses on the TFT screen. We aim to achieve this by defining classes for numeric and alphabetic input in Arduino IDE, enhancing the programming capabilities and functionality of the system.

Currently, we are facing some hardware limitations and time constraints, which have delayed the full implementation of these features. We plan to address these issues and complete the coding in the future, ultimately enabling the device to be more versatile and accessible via Wi-Fi for various users.

## 7. Appendices

ESP- S3-WROOM-U1 : esp32-s3-wroom-1_wroom-1u_datasheet_en.pdf (espressif.com)

ESP CAM : ESP32-CAM Camera Module Pinout, Datasheet, Features and Specs (components101.com)

TFT 1.8' display : 1.8" TFT Display Breakout and Shield Datasheet by Adafruit Industries LLC | Digi-Key Electronics (digikey.com)