American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBP
ISSN: 2997-9331

Design and Implementation a Vascular Vein Detector

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Received: 2024 29, Apr
Accepted: 2024 28, May
Published: 2024 22, Jun

Annotation: The design and implementation of a vascular vein finder serves as a medical monitoring device. It primarily comprises a main board and an LED light source. This device utilizes the varying absorption rates of near-infrared light. The vein finder operates at different wavelengths to facilitate the absorption of light by oxyhemoglobin within the surrounding tissues and vessels. Following photoelectroconversion, the data is filtered to reveal the veins. It is designed to simplify the process of locating veins. It is important to note that it aids in the search for superficial blood vessels beneath the skin, such as in adjunct intravenous diagnostics and the administration of intravenous therapies.

This device demonstrates the convenience of blood drawing for individuals of all genders and ages, including children, adults, and the elderly, for whom the blood drawing process can be particularly challenging due to health conditions or the difficulty in visualizing veins clearly. This can lead to delays in the stabilization process and blood withdrawal, causing discomfort to the patient due to repeated attempts at pricking in incorrect locations.

The device is capable of detecting superficial veins beneath the skin through the application of infrared light technology research and development. It provides a visual representation at the skin's surface to assist medical personnel in assessing the direction and distribution of blood vessels. Furthermore, the advanced model features various colors, which significantly enhance clarity and recognition.

Keywords: Vascular vein detection, Infrared imaging, Vein visualization, Near-infrared light, Arduino Nano, Hemoglobin absorption, Non-invasive diagnostics, Vein pattern recognition, Real-time image processing, Vein finder prototype

INTRODUCTION

Biometric security systems, including retinal scans, fingerprint sensing, iris recognition, and facial recognition, have gained significant attention in recent years. While these systems are highly accurate, they are also more susceptible to data theft and fraud. A relatively new method for biometric detection involves the extraction of vein patterns located beneath an individual's skin. Researchers have established that the vascular patterns of the human body are unique to each person and remain unchanged as individuals age. Furthermore, since the intricate vein structure is concealed beneath the skin, it is impossible to steal, forge, or replicate the vein pattern, as it cannot be inadvertently left behind. Due to these benefits, this technology is establishing its presence in the biometric recognition market. Additionally, a challenge faced by medical professionals today is the difficulty in accessing veins for intravenous drug delivery, catheter insertions, blood draws, and other medical procedures. Often, even experienced nurses and doctors struggle to accurately locate blood veins on the first attempt. Venipuncture is a routine procedure in healthcare environments. Therefore, this system can also be utilized for vein detection in medical applications.

Fig1. Vein Pattern in the dorsum

Fig 2. Vein puncture for medical tests

Hemoglobin serves as the primary element of red blood cells present in the bloodstream, responsible for transporting oxygen from the lungs via arteries and facilitating the return of carbon dioxide from tissues through veins back to the lungs. The vein pattern recognition system utilizes deoxidized hemoglobin. This is due to the fact that deoxidized hemoglobin absorbs infrared light, rendering the vein pattern visible when illuminated by a camera, while oxidized hemoglobin becomes nearly transparent.

In this paper, we concentrate specifically on the vein pattern from the Palma Dorsa. The objective of the project is to develop a vein recognition algorithm capable of extracting the veins from a user's hand. A novel absorption-based technique has been introduced to capture high-quality images using a camera and an infrared light source (IR LED). This project is divided into two phases: extraction and verification. During the extraction phase, the user's vein image is captured. Subsequently, image processing techniques are applied to enhance the quality of the vein image. Features are then extracted from the enhanced images and stored as templates. In the verification phase, a vein image of the test user is captured, followed by image preprocessing and feature extraction on the acquired image. Finally, the verification result is determined by comparing the similarity between the testing features and the stored templates.

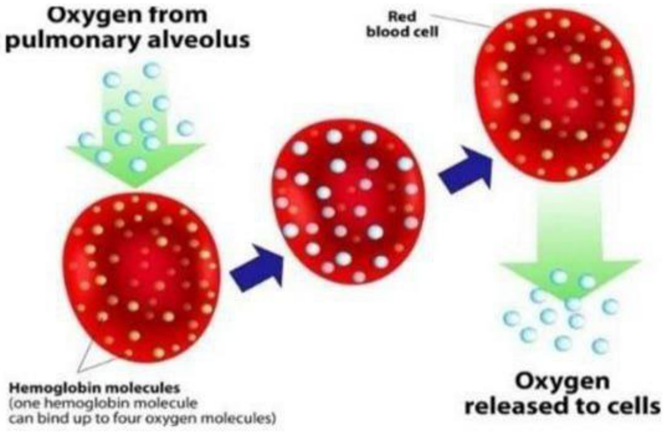


Fig 3. Hemoglobin Molecules

2. Literature Survey

A. The document entitled "Vein Detection System Utilizing Infrared Light" authored by Mayur Wadhwani, Abhinandan Deepak Sharma, Aditi Pillai, Nikita Pisal, and Dr. Mita Bhowmick states that it presents the design of a non-invasive subcutaneous vein detection system, which is implemented using near-infrared imaging technology and connected to a laptop for portability. The primary objective was to create a device that is both portable and cost-effective. A customized Charge Coupled Device (CCD) camera was employed to capture images of the veins, while software modules such as MATLAB and LabVIEW were utilized for processing.

The arm's image was obtained using a standard webcam, which had its visible inbuilt LEDs replaced with eight infrared LEDs. This modification aimed to enhance image quality, facilitating easier detection of vein patterns during segmentation. Subsequently, the region of interest was cropped and isolated through the application of filters to minimize noise and improve contrast.

Given that the images were captured with a modified webcam, significant noise was present. To address this issue, Gaussian and median filters were applied to mitigate the noise effects. Additionally, contrast enhancement was essential due to the faintness of the vein patterns. This enhancement was achieved using the Global Threshold method, which employs a bimodal histogram to calculate inter-variance. The adaptive histogram technique divides the image into tiles of 8x8 pixels and computes the histogram for each tile, resulting in improved contrast.

This paper explores near-infrared techniques for vein imaging. Consequently, the portable NIR vein detection system successfully visualized and identified vessels in the anterior forearm.

B. The document entitled "Low cost, high quality vein pattern recognition device with liveliness, workflow, implementations" authored by Septimiu Crisan and Bogdan Tebrean.

This document seeks to introduce and execute a durable, modular hardware solution that maintains an affordable entry point for academic research while delivering high-quality imaging of blood vessels, showcasing notable advancements compared to conventional scanning technologies. The addition of a sophisticated liveness detection system, which employs supplementary raw image analysis and external parameter assessments (such as image contrast, temperature, or skin reflexivity), outlines a potential framework for an open-source vein pattern recognition device.

The investigation that led to this document has primarily focused on the incorporation of a widely available device, the PI NOIR camera, into a vein pattern processing workflow. The PI NOIR works in conjunction with a Raspberry PI device to carry out all essential image processing tasks. The algorithm presented in this paper involves selecting a central 50x50 pixel region of interest from the raw image of the vein pattern after identifying the contour of the hand. For an image size of 320x240 pixels, this provides adequate data for analyzing the transitions in pixel values. The dimensions of the ROI are directly related to the optical acquisition module, and the active area was confined within the hand. For each pixel, the absolute difference between the values of the adjacent pixels—both raw and column—and the target pixel is computed. These differences are summed and stored for averaging purposes. Upon completion of the entire image area, the maximum and minimum difference between two successive pixels is determined. The resulting interval serves as an expression of the local contrast in the image and was utilized alongside the average pixel difference value. To enhance the system's protection against false samples, additional low-cost external devices are employed. The hand is illuminated by a series of red LEDs with a central wavelength of 650 nm. The light reflected from the surface of the hand is captured by two photodiodes positioned on opposite sides of the camera. The unique optical properties of the human hand provide a specific set of reflection values that are challenging to replicate. A secondary sensor for noncontact temperature measurement is integrated into the system. This paper has addressed the necessity for a modular hardware device that could serve as a potential standard in vein pattern recognition.

3. Materials and Methods

3.1. Materials

1. Arduino Nano

The Arduino Nano is a compact and versatile board that shares functionality with the Arduino Uno but is designed for projects requiring a smaller size, such as wearables, drones, and miniature robots. It utilizes the same Atmega328P microcontroller as the Uno, yet features a reduced footprint along with enhancements like eight analog inputs and a Mini-USB port for programming and communication. One of the key benefits of the Arduino Nano is its affordability and widespread availability, making it an attractive option for hobbyists and students alike. Additionally, its compatibility with various shields and modules designed for the Arduino Uno allows for easy expansion of its capabilities, positioning the Arduino Nano as an excellent choice for those seeking a compact and cost-effective solution for diverse projects.

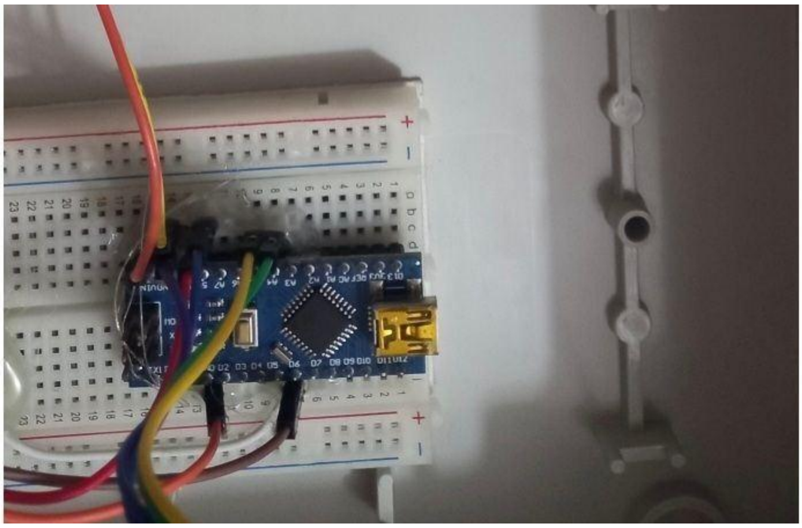


Fig 4. Arduino Nano

2. Lcd screen 2*16

An LCD 16×2 is an electronic device designed to display data and messages. As indicated by its name, it features 16 columns and 2 rows, allowing it to present a total of 32 characters (16×2=32), with each character composed of 5×8 (40) pixel dots. Consequently, the overall pixel count for this LCD amounts to 1280 pixels (32 x 40). The fundamental operation of an LCD involves the transmission of light through various layers and modules, which vibrate and align at a 90-degree angle, enabling the polarized sheet to permit light to pass through.

Fig 5. LCD Screen

3. Jumper wires

Jumper wires are essential components in electronics, featuring connector pins at both ends that facilitate connections between two points without the need for soldering. They are predominantly utilized with breadboards and various prototyping tools, enabling easy modifications to circuits as required. The simplicity of jumper wires is evident, as they are among the most fundamental elements in electronic projects. Typically, jumper wires are available in three configurations: male-to-male, male-to-female, and female-to-female. The distinction lies in the type of connector at each end; male connectors have protruding pins for plugging into sockets, while female connectors are designed to receive male pins. Male-to-male jumper wires are the most frequently used, particularly when establishing connections between ports on a breadboard.

Fig 6. LCD Screen

4. Battery

A battery serves as a source of electrical energy, comprising one or more electrochemical cells that connect externally to power various devices. When in operation, the positive terminal functions as the cathode, while the negative terminal acts as the anode, with the latter providing electrons that travel through an external circuit to the positive terminal. Upon connecting a battery to an external load, a redox reaction occurs, transforming high-energy reactants into lower-energy products, and the resulting free energy is released as electrical energy to the circuit. Although the term "battery" originally denoted a collection of multiple cells, its definition has broadened to encompass single-cell devices as well.

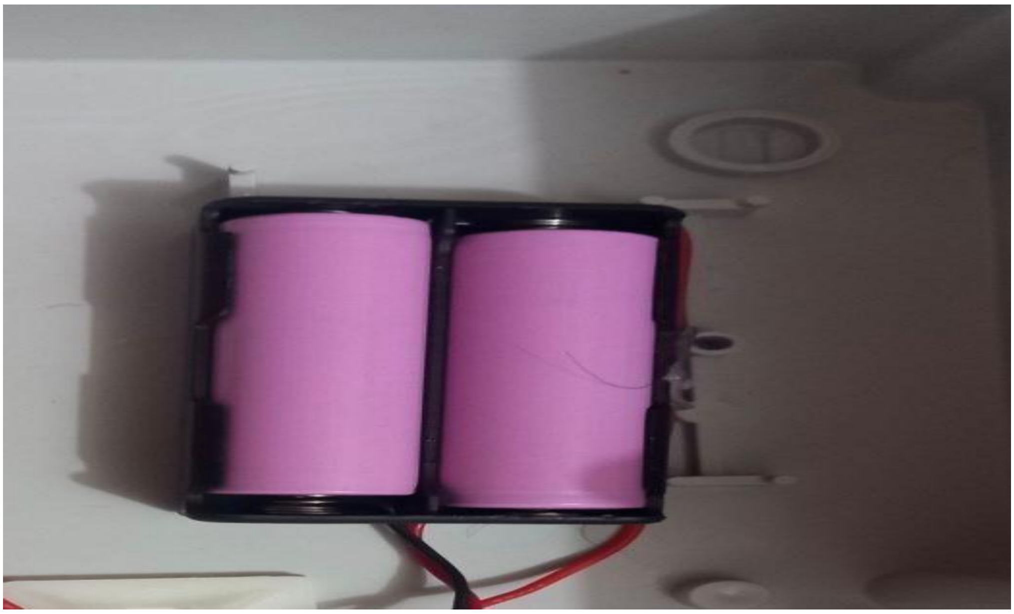


Fig 7. Battery

5. Transistor

A transistor is a compact semiconductor device that plays a crucial role in controlling and regulating the flow of current or voltage. It is also capable of amplifying and generating electrical signals, functioning as a switch or gate for these signals. Typically, a transistor is composed of three layers, or terminals, of semiconductor material, each of which is capable of conducting current.

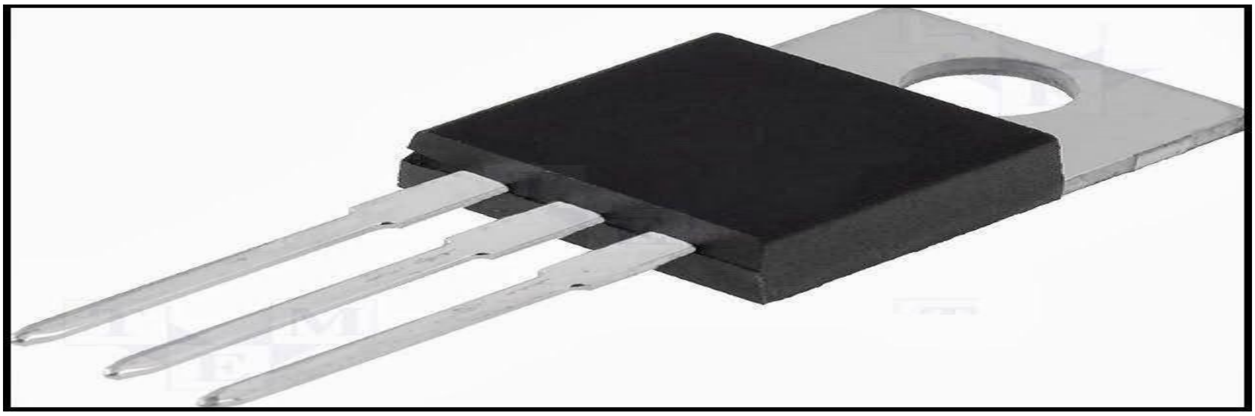


Fig 8. Transistor

6. IR sensor

Infrared (IR) technology plays a crucial role in various wireless applications, including remote controls and sensing devices. The infrared segment of the electromagnetic spectrum is divided into three primary regions: near IR, mid-IR, and far IR, each characterized by distinct wavelength ranges. The near IR region spans from 700 nm to 1400 nm, while the mid-IR region covers wavelengths from 1400 nm to 3000 nm. Lastly, the far IR region extends from 3000 nm to 1 mm, with each region tailored to specific applications and functionalities.

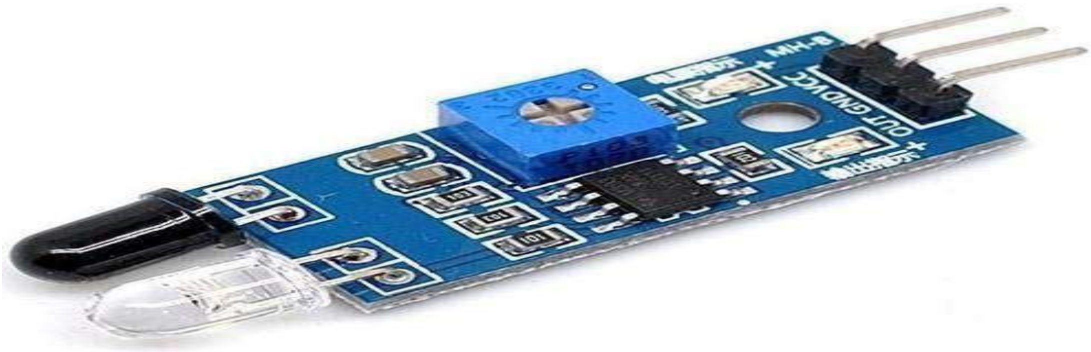
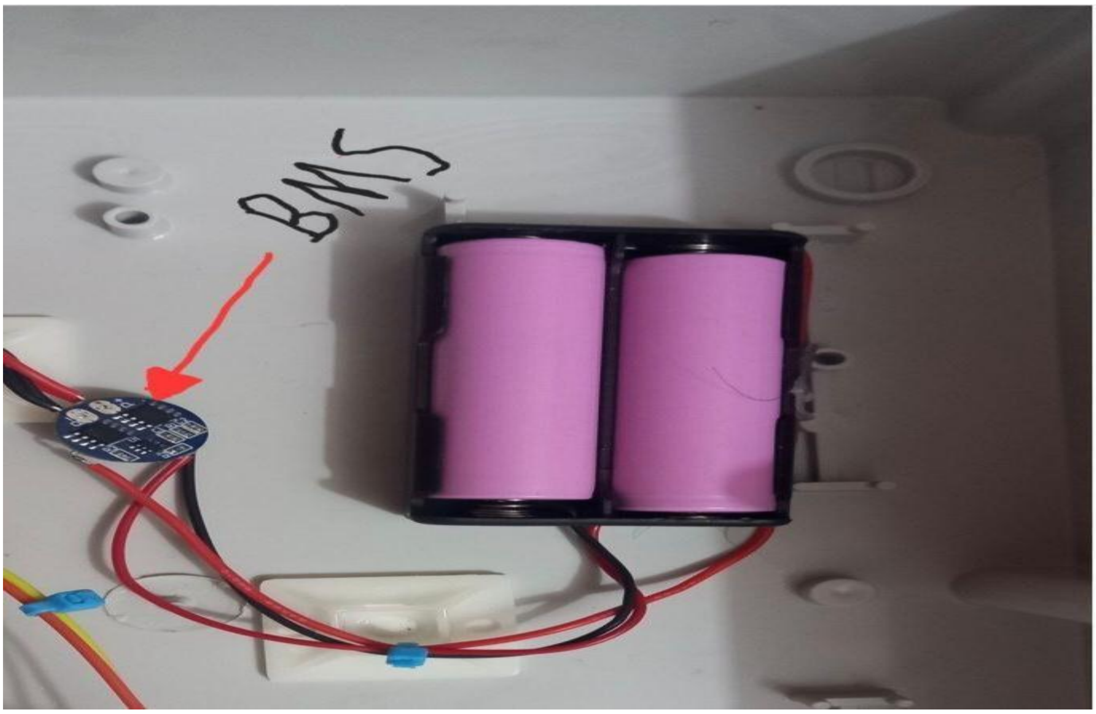


Fig 9. IR sensor

7. BMS battery

A Battery Management System (BMS) serves as a sophisticated component within a battery pack, overseeing its monitoring and management functions. Acting as the central control unit, the BMS is essential for ensuring the safety, efficiency, charging rates, and overall lifespan of the battery.



Bread board

A breadboard, also known as a solderless breadboard or protoboard, serves as a platform for constructing semi-permanent prototypes of electronic circuits. Unlike perfboards or stripboards, breadboards do not necessitate soldering or the alteration of tracks, making them reusable and particularly favored in educational settings. They can accommodate a wide range of electronic systems, from simple analog and digital circuits to entire central processing units (CPUs). However, modern breadboards exhibit higher parasitic capacitance, increased resistance, and less reliable connections compared to more permanent methods, which can lead to issues with physical stability and degradation. Consequently, signaling is typically limited to around 10 MHz, and functionality may be compromised even at lower frequencies.

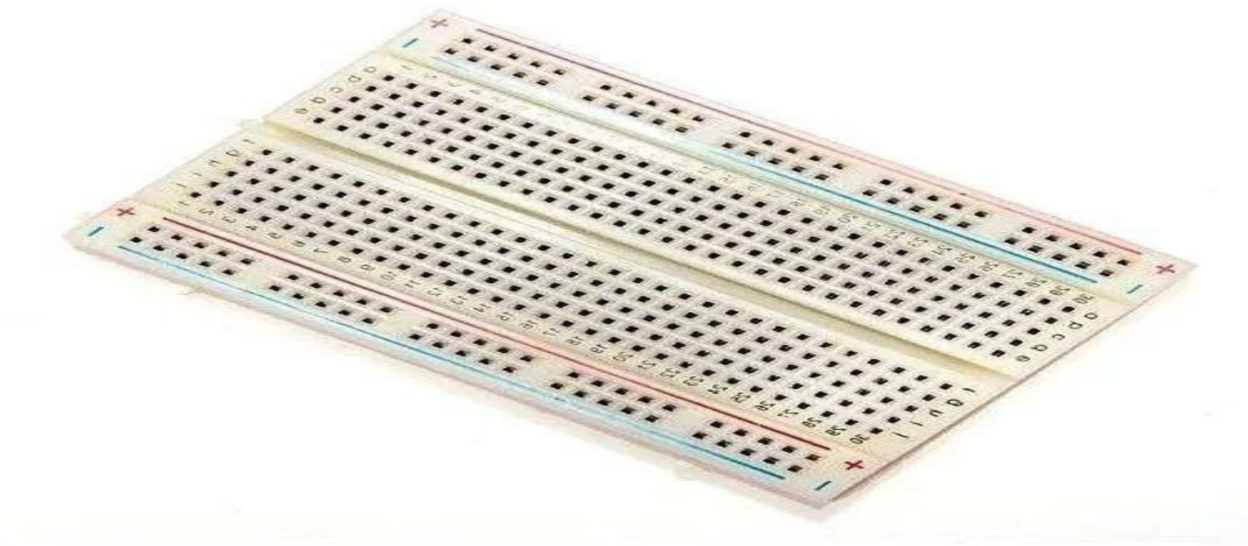


Fig 11. Bread board

9 . LED infrared

Near-infrared vein finders are specialized devices designed to enhance the visibility of veins for healthcare professionals. By utilizing near-infrared light reflection, these devices generate a detailed map of the veins beneath the skin. The resulting images can be either displayed on a screen or projected directly onto the patient's skin, facilitating more accurate venipuncture and improving patient care.

Fig 12. LED infrared

10. Voltage stabilizer (step down)

A transformer designed to reduce the voltage from primary to secondary is called a step-down transformer. The transformation ratio of a transformer will be equal to the square root of its primary to secondary inductance (L) ratio.

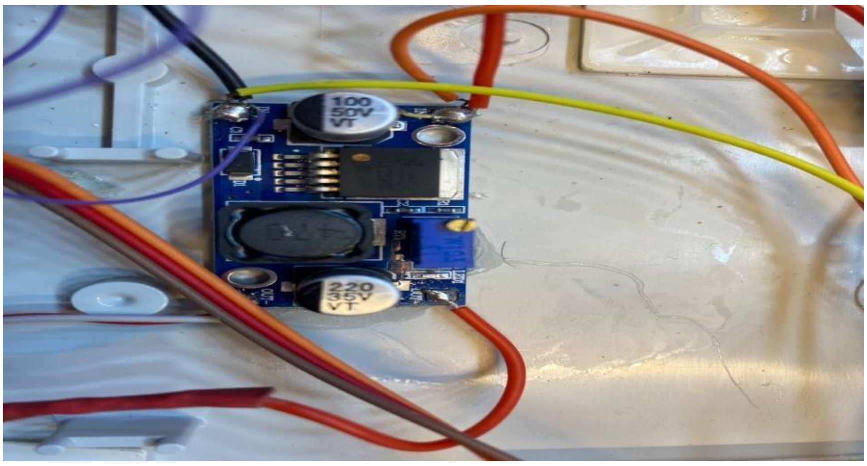


Fig 13. Voltage stabilizer

3.2. Methods

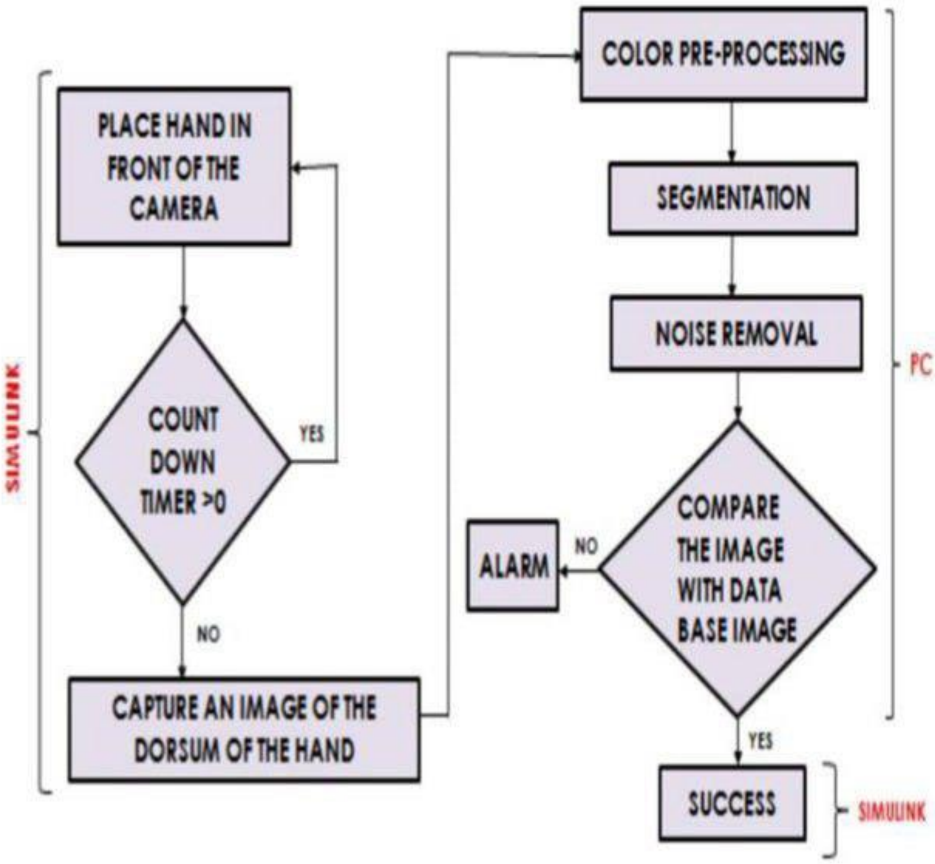


Fig 14. Flowchart of vein pattern recognition system

The hand is positioned within a black box, specifically placed in a fist mold in front of a camera at a designated distance. A timer is set to count up to 2 Simulink seconds; if the timer elapses without capturing an image of the dorsum, the hand must be repositioned for the image capture. Once the image is obtained, color pre-processing begins with the extraction of the hand from the background. This requires selecting an appropriate color model that can effectively differentiate any skin tone from the background, allowing for its removal. Following this, a segmentation process is applied, where the background is rendered black and the hand white using a threshold method. This step often generates noise pixels, which are subsequently eliminated through noise removal techniques. The same extraction process is then applied to the veins, which has potential applications in the medical field. In the context of biometric security systems, the extracted vein pattern is compared against a preloaded database image. Access is granted if the live image matches the database; otherwise, a false alarm is triggered to indicate a security breach.

Fig 15. The Final Form of the Designed Medical Device

4. Results

The practical implementation of the vein detection device yielded effective and observable outcomes in terms of vein visualization and system functionality. The device, constructed within a 20x30 cm plastic casing and equipped with four infrared LEDs, successfully emitted near-infrared light capable of penetrating the skin to reveal underlying superficial veins. When tested on individuals with varying skin tones and physiological characteristics—particularly children and individuals with obesity—the device consistently provided a visible contrast between veins and surrounding tissue.

Brightness control, managed via an Arduino Nano and an IR remote interface, allowed users to adjust the intensity of the LEDs from 0% to 100%, optimizing visibility based on individual conditions. The integration of an LCD screen displayed real-time brightness levels and system messages, enhancing user interaction and usability. The ability to control illumination precisely was crucial for reducing image noise and maximizing vein contrast.

Initial experimental trials indicated that the device was particularly effective in low ambient light conditions, where vein patterns became more pronounced. Users reported ease of use and rapid vein location, which reduced the number of unsuccessful venipuncture attempts. Furthermore, the rechargeable battery system and portable form factor increased the device's practicality in clinical and field environments.

While the hardware prototype functioned reliably, some challenges were observed, such as image blur due to hand motion and limitations in resolution due to the simplicity of the camera module. However, the overall results demonstrate that the device meets its design goals and provides a viable solution for non-invasive vein detection.

5. Conclusion

The portable NIR vein detection system successfully visualized and identified vessels from the dorsum, utilizing various image algorithms, with threshold segmentation proving most effective in MATLAB. Real-time processing was achieved through SIMULINK, allowing for the collection of sample images from individuals with diverse skin tones and muscle structures, resulting in the desired image outputs. However, the portability of the infrared imaging system introduced challenges related to motion artifacts. Despite these issues, the objective of creating a cost-effective, portable vein imaging system has been realized. While the current database remains limited and insufficient for drawing definitive conclusions about vein pattern discrimination across a large population, preliminary experiments suggest that the minutiae of vein patterns hold promise as a biometric feature for personal verification within a moderately sized user group. Ongoing efforts are focused on expanding the database, although the collection of vein pattern data is inherently time-consuming. The findings indicate the potential of utilizing hand-vein pattern minutiae as distinguishing features in hand-vein imaging.

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Appendix A: Arduino Code

```
#include <IRremote.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);
int bright = 0;
int before = 0;
int out = 5;
int steps = 5;
int RECV_PIN = 6;
IRrecv irrecv(RECV_PIN);
decode_results results;
void setup() {
  lcd.init();
  lcd.backlight();
  irrecv.enableIRIn();
  pinMode(out, OUTPUT);
  lcd.setCursor(0, 0); lcd.print("| VEIN FINDER |");
  lcd.setCursor(0, 1); lcd.print("|   PROJECT   |");
  delay(2000); lcd.clear();

  lcd.setCursor(0, 0); lcd.print("| AL-Hilla    |");
  lcd.setCursor(0, 1); lcd.print("| University  |");
  delay(2000); lcd.clear();
  lcd.setCursor(0, 0); lcd.print("|Medical device|");
  lcd.setCursor(0, 1); lcd.print("| engineering  |");
  delay(2000); lcd.clear();
```

```
  lcd.setCursor(0, 0); lcd.print("| THIS PROJECT |");
  lcd.setCursor(0, 1); lcd.print("| WAS MADE BY  |");
  delay(2000); lcd.clear();
  lcd.setCursor(0, 0); lcd.print("| Haider Salam |");
  lcd.setCursor(0, 1); lcd.print("| Abbas Jabbar |");
  delay(2000); lcd.clear();
  lcd.setCursor(0, 0); lcd.print("| Safa Ameer   |");
  lcd.setCursor(0, 1); lcd.print("| Ahmed Alaa   |");
  delay(2000); lcd.clear();
  lcd.setCursor(0, 0); lcd.print("| supervised   |");
  lcd.setCursor(0, 1); lcd.print("| by           |");
  delay(2000); lcd.clear();
  lcd.setCursor(0, 0); lcd.print("* Noor Salman *");
  lcd.setCursor(0, 1); lcd.print("     Ali       ");
  delay(2000); lcd.clear();
  lcd.setCursor(0, 0); lcd.print("Starting");
  delay(200); lcd.setCursor(0, 0); lcd.print("Starting .");
  delay(200); lcd.setCursor(0, 0); lcd.print("Starting ..");
  delay(200); lcd.setCursor(0, 0); lcd.print("Starting …");
  delay(200);
  lcd.setCursor(0, 1); lcd.print(" Welcome 😊 ");
  delay(1000); lcd.clear();
}

void loop() {
  int maap = map(bright, 0, 255, 0, 100);
  lcd.setCursor(0, 0); lcd.print("Light Brightness");
  lcd.setCursor(5, 1); lcd.print(maap); lcd.print("%");
  if (irrecv.decode(&results)) {
    if (results.value == 0xFF38C7) {
      if (before == 0) {
        analogWrite(out, 51);
        bright = 51;
        before = 1;
        lcd.clear();
      } else {
        digitalWrite(out, LOW);
        bright = 0;
        before = 0;
        lcd.clear();
      }
    }
    irrecv.resume();
  }
}
```