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Implementation and Design of a Blood Vessels IR Sensor

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***Abstract*—Medical professionals often perform venipuncture or intravenous (IV) cannulation/treatment. They often face challenges in obtaining IV access. The usual methods involve visual inspection and palpation, which implies a high failure rate. The current alternatives include devices that are too expensive or could irritate neonates' skin. Aim: Our device offers a low-cost, non-invasive, accessible alternative that uses Near-Infrared Spectroscopy (NIRS) technology to locate blood vessels, to aid in IV treatments. Methodology: We revised the state of the art for blood vessel visualization in real-time, allowing us to detect areas of opportunity. After that we designed and assembled our portable NIRS device, using 3 IR-LEDs emitting a wavelength of 940nm, an HD Camera with Bluetooth capability, digital filters coded in Python, and an Android app for visualizing in real-time. Results: we observed difficulty detecting blood vessels in individuals with clear skin but found success visualizing blood vessels in darker skin complexions, an area where other devices usually fail.**

***Index Terms*—IR Sensor, blood vessels detection, skin pigmentation, bioimaging, implementation for detection.**

I. Introduction

Medical personnel frequently encounter challenges in obtaining Intravenous (IV) access, particularly with diverse patient populations such as obese individuals, those with higher skin melanin concentration, neonates, and geriatric patients [1, 2]. Factors like previous chemotherapy treatment or intravenous drug use history can complicate the procedure [3]. Venipuncture and IV cannulation are integral invasive procedures in modern medicine, with approximately 92.5% of patients undergoing treatment via the IV route [4].

Venipuncture refers to the act of inserting a needle into a vein, mostly the median cubital vein, to obtain a blood sample that will be analyzed in the laboratory, assisting in the diagnosis and subsequent holistic treatment of the patient. On the other hand, IV Cannulation refers to the procedure of inserting a tube or cannula into a peripheral vein to gain access to the circulatory system, for the administration of IV fluids related to hydration or nutritional support, IV medications, transfusion, or patient monitoring [5]. These procedures demand specialized knowledge, communication skills, and patience to prevent pain and complications [6].

The most common methods of vein selection are visual inspection and palpation. Failing in venipuncture can result in various complications, including thrombosis, hematoma due to poor technique or vein selection, arterial punctures (which have a similar location to veins), or nerve injury leading to extreme reactions in specific patient populations [7]

Approximately a third of patients require multiple punctures and cannulation attempts due to difficulties in vein localization [2]. Test result variability may arise from procedural failures, further emphasizing the need for innovative solutions [4] Near-infrared spectroscopy (NIRS) has emerged as a crucial tool in medical diagnostics, offering real-time insights into biological tissues [9-10]. NISR operates within the 700 to 3000nm wavelength region, allowing for measurement of the absorption and scattering of NIR light, particularly interacting with chromophores like oxy- (O2Hb) and deoxyhaemoglobin (HHb) and myoglobin [11]. This technology has been demonstrated to be versatile and its utility in monitoring blood flow and oxygenation levels, with applications in medical procedures and research contexts (Ferrari et al., 2004). Addressing the challenge of blood vessel visibility, Francisco (2021) notes limitations in conventional methods, leading to the proposition of employing NIR to enhance blood vessel visualization. Our research presents an innovative approach utilizing Infrared (IR) imaging technology to develop a low-cost, non-invasive, and contactless IR imaging device. Current blood vessel detection devices are costly, cover limited surface areas, and most are impractical for neonates [9]. Our initiative aims to aid in the better realization of venipuncture and IV cannulation procedures by mitigating uncertainties in vein localization, providing a reliable solution to enhance patient care. The device incorporates a camera system with an IR filter, strategically positioned IR LEDs, and Python-written filters for digital image processing. Our research explores the design explores the design principles and potential applications of this novel device, promising significant contributions to blood vessel visualization, with implications for precision, efficiency, and patient-centric medical procedures.

II. Materials and Methods

A. System Model

910 nm near-infrared (NIR) light is often used in night vision applications, camera lighting, and other applications because it can penetrate better through certain materials and be less visible to the human eye. A slightly shorter wavelength, such as 710 nm, has a better ability to penetrate the skin compared to visible light. This allows some of the light to reach the veins below the surface of the skin. The combination of 910 nm and 710 nm

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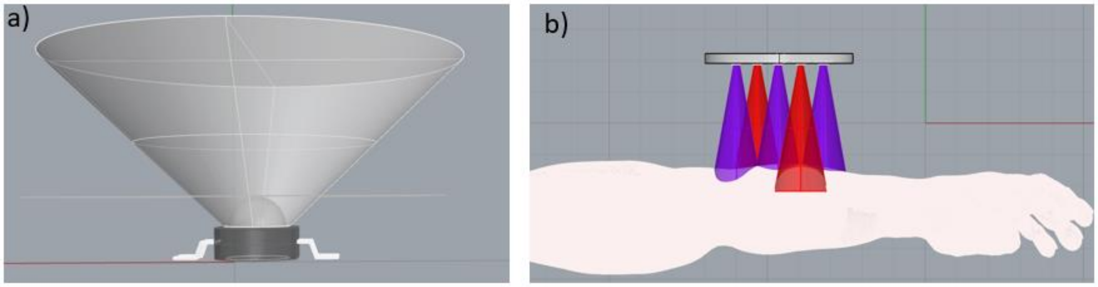

Fig. 1. Infrared LEDs. a) Aperture 120 degrees and b) Combination of LEDs of different lengths at 30mm equidistant

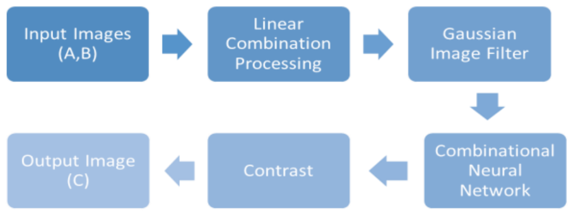

Fig. 2. Diagram of the proposed algorithm

LEDs has unique absorption and reflection characteristics that may be relevant to improving the contrast between veins and surrounding tissues. The blood's hemoglobin absorbs light at these frequencies differently, which makes veins easier to see.

The choice of LED configuration with a 120-degree aperture allows for an even distribution to cover a specific field of view, covering a larger area with fewer devices, allowing a greater number of veins to be detected and visualized in a single go, as well as reducing energy consumption and maximizing energy efficiency, as shown in Figure 1a. The intensity of the light decreases with distance, and the choice of 20 mm may be necessary to ensure sufficient illumination for penetration through certain means or adaptation to the spectral characteristics of the objects to be illuminated. Placing the 3 x 910nm LEDs and 2 x 710nm LEDs equidistant at 20 mm allows for concentrated illumination in interest, avoiding unnecessary light scattering and ensuring that most of the light energy reaches the veins, as shown in Figure 1b.

This work was done using a webcam, from which an infrared light-blocking filter was removed and replaced with one that permits the light to pass through. To improve the detection of the veins, an array of LEDs was added to the camera. The infrared imaging system is based on a commercial digital camera, "Logitech Webcam Stream Cam", which has an image resolution of 1920 x 1080 pixels with the ability to acquire images at 60 frames per second, has a USB connection for sending images to a computer, in addition to being factory-equipped with a light filter that allows the passage of wavelengths from the visible spectrum.

The position and angle at 45 degrees between the camera's direction of the LEDs and the direction of the camera can be strategic to minimize glare or unwanted reflections in the captured image by highlighting features that, through image processing and contrast techniques, edge enhancement, filtering, and applying edge detection algorithms, identify and map in the image to highlight vascular features.

The images obtained were processed using the for-image processing, using real-time code, two images are acquired as input: one in color and the other in grayscale. Using the technique of linear combination of these images to attenuate or highlight certain characteristics of both images, that is, the linear combination of two images A and B, involves adding them multiplied by two coefficients c1 and c2, obtaining (c1×A) +(c2×B) that when adjusting the coefficients in an image, the information of the color image is subtracted from the grayscale image. Subsequently, a Gaussian filter is applied that allows simulating the random affectation of the pixels of an image with uniformly distributed values, smoothing the resulting image and classifying the pixels by intensity level, eliminating noise, improving quality, softening the edges, and obtaining a more accurate segmentation of patterns for image analysis with vascular structures of interest.

After preprocessing with a Gaussian filter, a convolutional neural network (CNN) is applied for vein image analysis, such as detecting, segmenting, or classifying veins in the image. The model will automatically learn features and patterns relevant to the specific task. How to identify the location of the veins in the image. Additional contrast post-processing, false positive removal, or refinement of vein contours is performed after CNN inference. The contrast in images adjusts the difference in intensity between light and dark areas to visualize the veins and their contours more clearly, highlighting areas of narrowing or dilation of blood vessels. Figure 1 shows the diagram of the proposed algorithm.

III. Results

An infrared imaging system was built, and a database was generated considering a total of 30 volunteers. The age range of the subjects is 25 to 35 years, of which 15 are women and 15 are men. The space where the images are captured is a closed room that prevents sunlight from passing through and has artificial lighting. The distance between the object of interest and the camera is 45 cm, to ensure a horizontal view width of 28 cm, covering the forearm region, given the 120° viewing angle of the camera.

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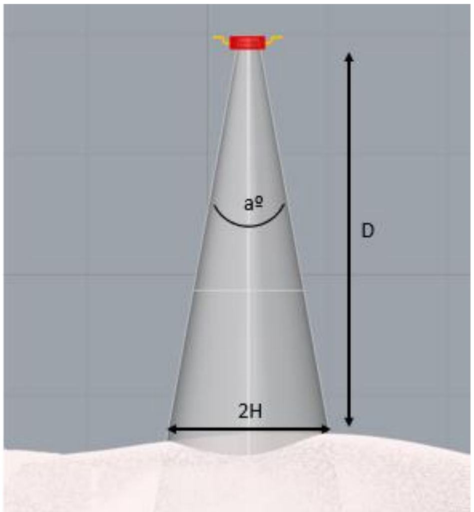

Fig. 3. Relationship of the horizontal angle of view (a = 120 °) to the distance to the object (D = 25 cm) and the width of view (2H = 25 cm)

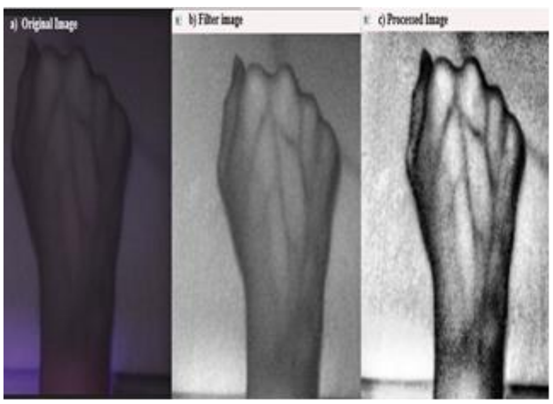

Fig. 4. Image processing result

The images obtained with the system contain three main areas to be segmented, the first area to consider is the background of the image, this is the base where the patient placed the forearm with a Gaussian filter, the second region is the corresponding one applying the neural network itself to the venous distribution, figure 4.

IV. Conclusion

In this work, an accessible and low-cost system for the detection of vein distribution was presented, using reflective infrared illumination, making use of the property of deoxygenated hemoglobin to absorb this wavelength. The filter made of rebellious photographic film proved its efficiency by eliminating wavelengths from the visible range, allowing passage into the infrared range, thus obtaining controlled lighting conditions. The array of infrared LEDs helped to uniformly illuminate the region of interest, improving the contrast of the captured images. The combination of 910 nm and 710 nm wavelength selected for the lighting system presented the best contrast.

The skin pigmentation does not influence the process of getting venous distribution, based on the photos stored in the database. Remarkably, we found that those with clear skin had more trouble seeing blood vessels, defying the accepted wisdom that people with darker skin have more difficulty seeing NIR devices.

As perspectives of this work, its implementation in a portable device of continuous response, which projects the final image on the captured region, has been considered; therefore, it is essential to minimize execution times. It has been considered to continue working with the neural network algorithm since it has the shortest execution time. According to the images obtained, skin pigmentation does not influence the venous distribution process. Contrary to popular belief, people with darker skin have a harder time seeing near-infrared (NIR) devices. Surprisingly, we found that people with light skin had a harder time detecting blood vessels.

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