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Original article

Portable Hand Vein Finder System Based on Near-Infrared Illumination

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Abstract
Vein visualisation is critical in medical procedures such as venipuncture, where accurate identification of superficial veins can help reduce patient discomfort and procedural failure. However, conventional vein identification relies largely on visual inspection and palpation, which may be challenging in cases of difficult venous access. Near-infrared (NIR) imaging provides a non-invasive approach to enhancing the visibility of superficial veins beneath the skin. This study presents the development of a portable NIR vein visualisation system using a 64-bit Raspberry Pi, a modified HBVCAM GC0308 camera, twelve 850 nm NIR LEDs, and a TFT LCD. The system captures NIR images of the hand, processes them using image enhancement techniques implemented on the Raspberry Pi, and displays the resulting vein patterns in real time. A rechargeable 5 V power bank provides portable power. Experimental evaluation demonstrated that the system successfully visualised superficial veins in different anatomical regions and among participants with different skin pigmentation conditions. Higher vein contrast was generally observed in participants with light skin, while vein patterns remained distinguishable, although with relatively lower contrast, in participants with dark skin. The system achieved real-time image acquisition and processing, producing clear vein images without noticeable processing delays. The developed prototype demonstrates the feasibility of a compact and portable NIR-based approach to superficial vein visualisation. Its relatively simple hardware configuration and use of commercially available components offer potential for a cost-effective solution to assist venipuncture procedures. Further improvements in camera technology and image processing could enhance its performance and support future clinical and educational applications.
Keywords. Near-infrared Imaging, Vein Visualisation, Venipuncture, Biomedical Imaging, Raspberry Pi.

Introduction

Venous access is an essential component of clinical practice and is routinely performed for blood collection, intravenous therapy, medication administration, and emergency care [1]. Although it is a common medical procedure, obtaining reliable venous access remains challenging in certain patient populations. The procedure is particularly difficult in pediatric patients, elderly individuals, obese patients, patients with chronic diseases, and individuals with dark skin pigmentation, where superficial veins are often difficult to identify. Consequently, repeated cannulation attempts may be required, increasing patient discomfort, procedural time, healthcare costs, and the risk of complications such as bruising, hematoma, and infection [2,3]. Conventional vein localisation is primarily performed through visual inspection and manual palpation. Although these techniques are widely used in clinical practice, their effectiveness depends on the clinician's experience as well as the patient's vascular characteristics [4,5]. When veins are poorly visible or cannot be palpated, these traditional approaches often lead to repeated cannulation attempts, highlighting the need for reliable technologies that improve vein visualization and facilitate venipuncture [4,5].

Near-infrared (NIR) imaging has become an effective non-invasive approach for visualising superficial veins [6]. Within the NIR spectral range (700–1000 nm), light penetrates biological tissue and interacts with tissue through absorption and scattering [6-8]. Because haemoglobin absorbs more NIR light than the surrounding tissue, blood vessels reflect less light to the imaging sensor and therefore appear darker than the adjacent tissue, providing sufficient contrast for vein visualisation [8-10]. This optical principle enables real-time imaging without exposing patients to ionising radiation or requiring contrast agents. Among the wavelengths commonly employed for NIR vein imaging, including 760, 850, and 940 nm, the 850 nm wavelength has been widely adopted because it provides a favourable balance between tissue penetration, haemoglobin absorption, and image contrast [11]. Consequently, numerous NIR-based vein visualisation systems have been developed using different illumination arrangements, imaging sensors, and image-processing algorithms [12, 13]. Despite the encouraging results reported in previous studies, many commercially available systems remain relatively expensive or dependent on specialized imaging hardware, limiting their accessibility, particularly in resource-limited healthcare environments [14].

Recent advances in embedded computing and open-source computer vision have facilitated the development of compact and affordable medical imaging systems. To address the limitations of existing vein visualisation systems, this study proposes a portable near-infrared vein visualisation system that combines 850 nm illumination with real-time image processing on a Raspberry Pi platform. The proposed prototype is designed to provide a practical, low-cost, and non-invasive solution for assisting vein localisation during venipuncture, with the potential to improve procedural efficiency and reduce repeated cannulation attempts.

Several studies have investigated near-infrared (NIR) imaging for superficial vein visualization using different imaging sensors, illumination wavelengths, and image-processing techniques. (Table 1) summarizes representative studies in this field.

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Table 1. Comparison of representative NIR-based vein visualization systems.

Ref/ Year	Processing Hardware	Light source	Camera	Image Processing
[15]/2020	Raspberry Pi	850 nm LEDs	NoIR camera	Image processing and image projection
[16]/2020	Laptop PC	Five 850 nm NIR LEDs	Modified WiFi CMOS camera (IR filter removed)	MATLAB (grayscale conversion, CLAHE, contrast adjustment)
[17]/2023	Pc	Infrared lamp	Modified webcam	Histogram equalization, thresholding, segmentation, edge detection
[18]/2024	Embedded platform	NIR LEDs	NIR Camera	Image enhancement, PSNR, SSIM
[19]/2025	Raspberry Pi	850 nm NIR LEDs	Infrared Camera	MATLAB, Python
[20]/2025	Pc	625, 850 & 940 nm LEDs	Arducam CMOS IMX291 (IR filter removed)	MATLAB, 2D hessian–frangi filter
[5]/2026	Pc	940 nm NIR LEDs	Modified webcam	Conventional image processing

Methods

System Overview

The proposed portable vein visualisation system uses NIR imaging to visualise superficial veins in real time. The system integrates illumination, image acquisition, image processing, and image display into a compact portable platform. During operation, the hand is illuminated by an 850 nm NIR LED array, and the reflected light is captured by the HBVCAM GC0308 camera. The acquired images are processed in real time by the Raspberry Pi before being displayed on the TFT LCD, as illustrated in the system schematic diagram (Figure 1).

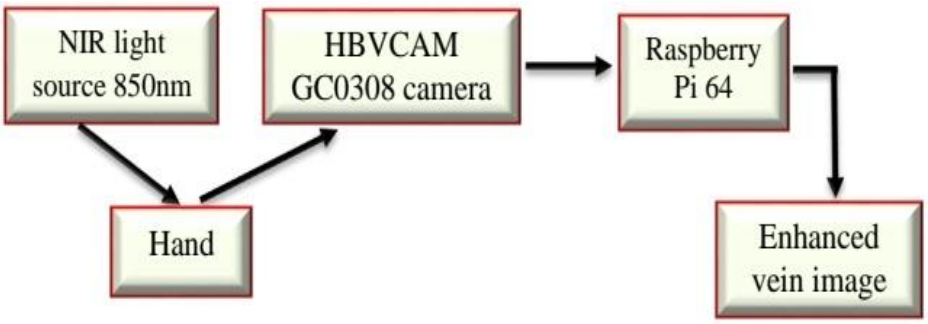


Figure 1. Schematic diagram of the proposed portable system.

Hardware Components

The hardware components of the proposed vein visualisation system are shown in (Figure 2) and described as follows:

Raspberry Pi

The processing unit of the proposed system was a 64-bit Raspberry Pi single-board computer. It was selected because of its compact size, low power consumption, and capability to execute Python and OpenCV-based image-processing algorithms in real time [21].

NIR LED Array

Twelve 850 nm NIR LEDs arranged in a single circular array were used as the illumination source. The 850 nm wavelength was selected based on previous studies reporting favourable venous image contrast within the 800–850 nm range and effective visualisation of subsurface blood vessels around 850–900 nm [9,22].

HBVCAM GC0308 Camera

Image acquisition was performed using an HBVCAM GC0308 0.3 MP USB camera. The camera's built-in infrared (IR-cut) filter was removed to allow near-infrared light to reach the image sensor, enabling the acquisition of images under NIR illumination. The camera was selected for its compatibility with the Raspberry Pi platform [23].

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TFT LCD Display

A 3.5-inch thin-film transistor liquid crystal display (TFT LCD) was employed to display the processed vein images in a real time.

Power Supply

Portable operation was achieved using a rechargeable 5 V, 3 A power bank, which supplied power to the system during operation.

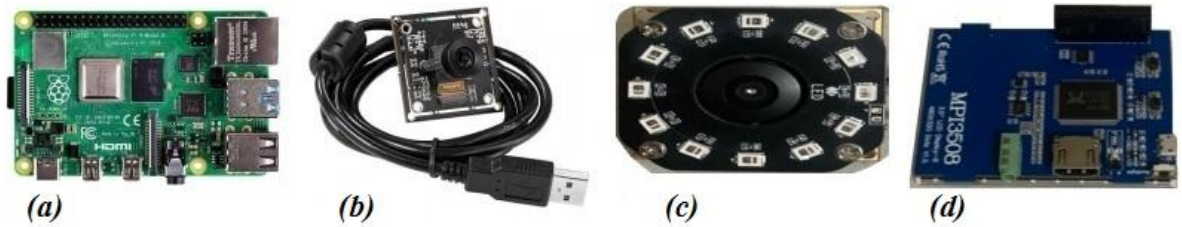


Figure 2. Hardware components of the proposed system: (a) Raspberry Pi, (b) HBVCAM GC0308 USB camera, (c) NIR LED array, and (d) TFT LCD.

After integrating the hardware components and implementing the image-processing software using Python and OpenCV, an initial prototype was developed to verify system functionality, image acquisition, and real-time image processing. Following successful validation, the device was assembled into a compact enclosure to improve portability, protection, and ease of use. (Figures 3 and 4) illustrate the initial and final configurations of the proposed system, respectively. The final configuration was used for all subsequent experimental evaluations.

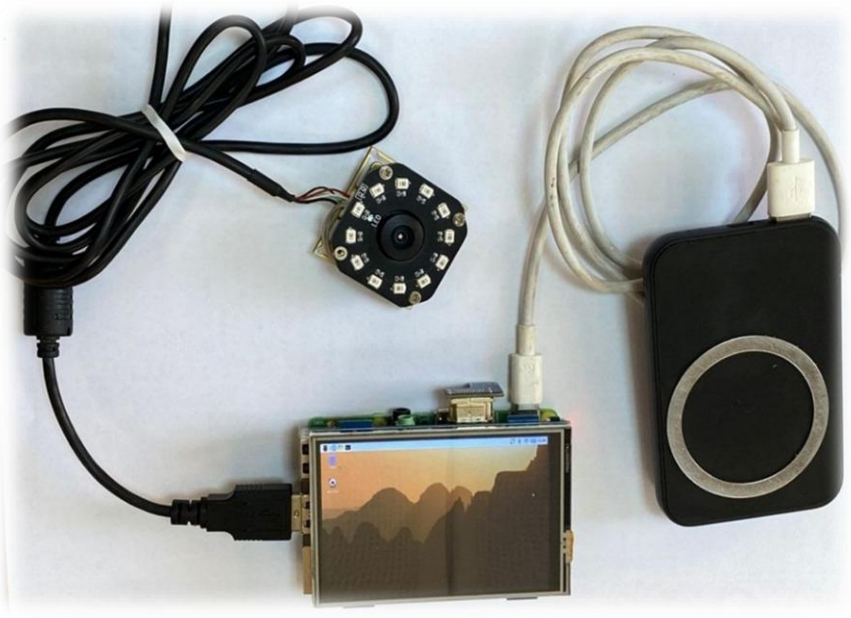


Figure 3. Initial prototype of the proposed NIR vein visualisation system.

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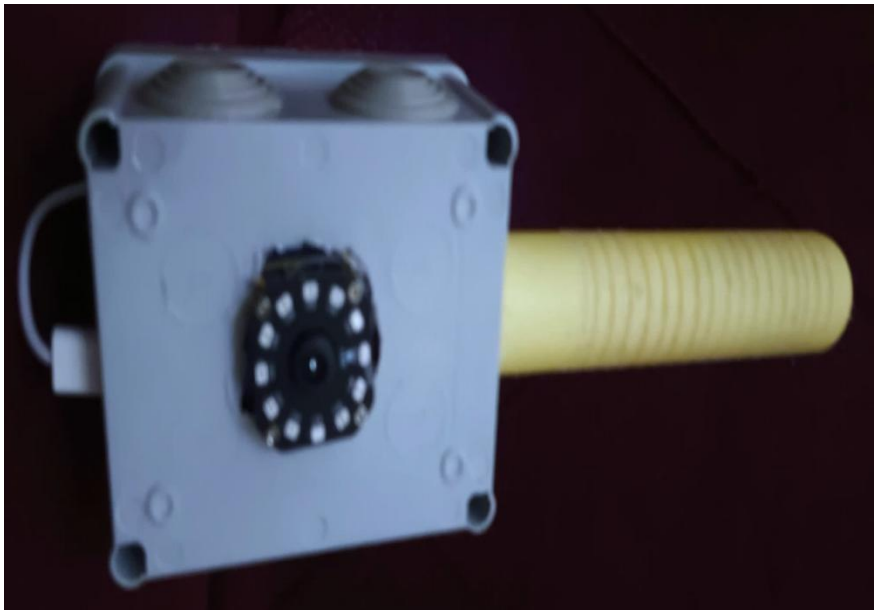


Figure 4. Final prototype of the proposed NIR vein visualisation system.

Software and Image Processing

The image-processing software was developed using Python and the OpenCV library and executed on the Raspberry Pi. After image acquisition by the HBVCAM GC0308 camera, the captured RGB image was converted to grayscale to simplify processing. Contrast enhancement was then applied to improve the visibility of superficial veins by increasing the distinction between veins and surrounding tissues. Finally, the enhanced vein image was displayed on the TFT LCD in real time.

Experimental Setup

Study Sample

The proposed vein visualisation system was evaluated using 26 volunteers aged between 16 and 50 years. The study included 22 participants with light skin and 4 participants with dark skin. All experiments were conducted at Al-Zawia Central Hospital over a two-day period (19–21 April 2026).

Ethical Approvals

Ethical approval was granted by the Biosafety and Bioethics Committee (NBC:018.H.26.138). Permission to conduct the study was obtained from the hospital administration. All participants were informed about the purpose and procedures of the study, and verbal informed consent was obtained from each participant. Participation was entirely voluntary.

Experimental Procedure

The experiments were conducted under indoor lighting conditions. During image acquisition, the participant's hand or forearm was positioned approximately 15-20 cm from the camera and the 850 nm NIR LED array. Images were acquired from two anatomical regions, namely the dorsal hand and the forearm. The captured images were processed in real time by the Raspberry Pi and subsequently displayed on the TFT LCD for qualitative evaluation of superficial vein visibility.

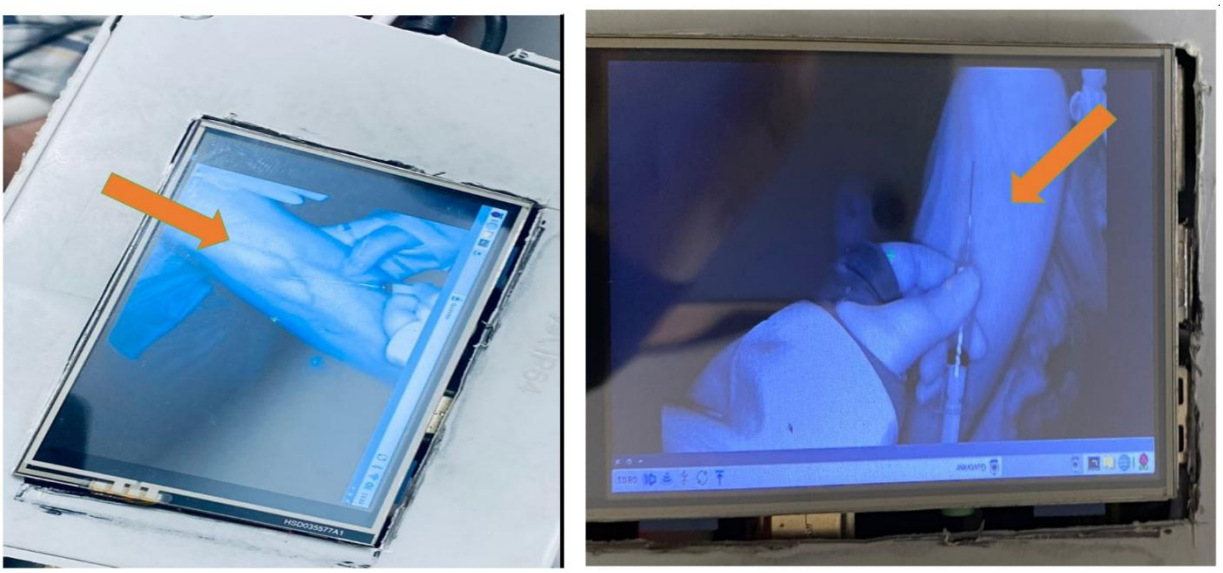
Results

The proposed portable vein visualisation system was evaluated on participants with different skin tones and anatomical regions. Representative results obtained from the forearm and dorsal hand are presented to demonstrate the system's ability to visualise superficial veins under various imaging conditions.

Forearm Vein Visualisation

(Figure 5) presents vein results obtained from the forearm of participants with light and dark skin. Clear superficial vein patterns are observed in both cases.

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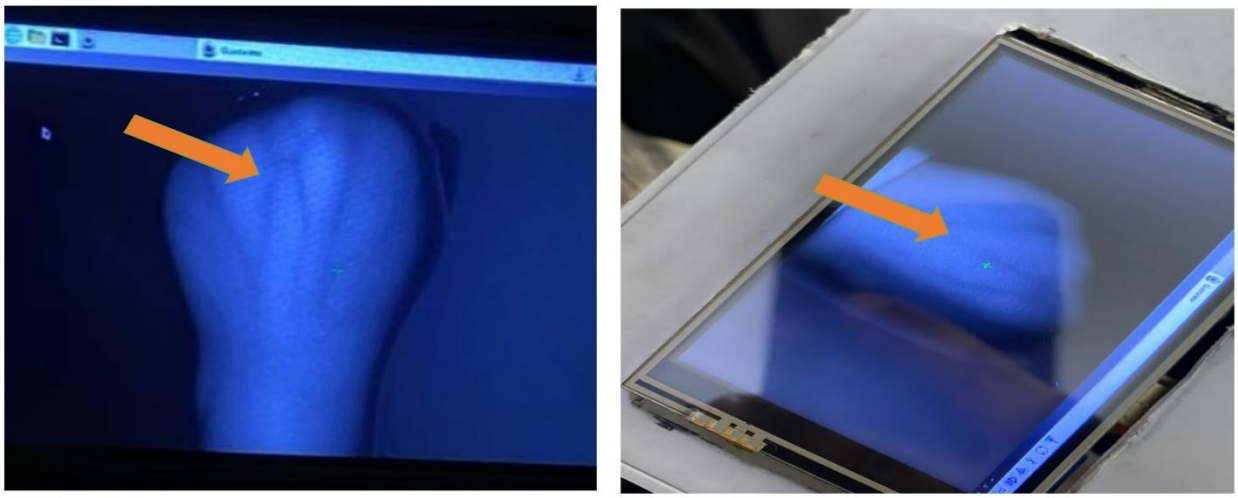


(a) ***(b)***

Figure 5. Vein visualisation obtained from the forearm of participants with (a) light skin and (b) dark skin.

Dorsal Hand Vein Visualisation

(Figure 6) presents the corresponding results obtained from the dorsal hand, where the superficial veins are also clearly visible in both skin types.



(a) ***(b)***

Figure 6. Vein visualisation obtained from the dorsal of participants with (a) light skin and (b) dark skin.

Discussion

The experimental results demonstrate that the proposed portable vein visualisation system can produce clear images of superficial veins in real time using 850 nm NIR illumination. This performance is achieved through the integration of an 850 nm NIR LED array, a modified HBVCAM GC0308 camera with its infrared (IR-cut) filter removed, and a Raspberry Pi image-processing platform. The selected wavelength enables NIR light to penetrate superficial tissues, while differences in light absorption and scattering between blood vessels and surrounding tissues contribute to the optical contrast required for vein visualisation. Image processing further enhances the visibility of the vascular patterns. Moreover, the use of commercially available components resulted in a compact and portable system that does not require specialised vein-imaging equipment.

Differences in vein visibility were observed between participants with light and dark skin. Vein patterns generally exhibited higher contrast in participants with light skin, whereas relatively lower contrast was observed in participants with dark skin. This variation may be partly associated with differences in skin optical properties, particularly melanin absorption in the epidermis. Although NIR light is less strongly absorbed by melanin than visible light, some incident radiation may still be absorbed before reaching the underlying blood vessels. Tissue scattering and variations in vein depth may also influence the amount of reflected light captured by the camera. In addition, the absorption characteristics of haemoglobin contribute to the contrast between blood vessels and surrounding tissues. The combined influence of these optical factors may therefore affect vein visibility across different skin pigmentation conditions [8,9,16]. Nevertheless, the system successfully visualised superficial vein patterns in both groups of participants. Further investigation involving a larger and

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more diverse sample is required to evaluate its performance across a wider range of skin pigmentation conditions. The findings of this study are consistent with previous research on NIR-based vein imaging. Study [15] demonstrated vein visualisation using an 850 nm LED array and a Raspberry Pi platform, while study [5] reported effective vein enhancement using 940 nm illumination. Similarly, study [10] demonstrated the effectiveness of both 850 nm and 940 nm wavelengths for superficial vein imaging. Furthermore, studies [17] and [18] reported improvements in vein visibility through image enhancement techniques. In comparison with these approaches, the proposed system integrates NIR illumination, image acquisition, and processing using a relatively simple hardware configuration comprising an HBVCAM GC0308 USB camera, a Raspberry Pi, and twelve 850 nm NIR LEDs. Its compact design and use of readily available components make it a practical and potentially economical approach to portable vein visualisation. The system may therefore offer a useful aid for healthcare professionals during venipuncture, particularly in healthcare settings with limited resources.

Conclusion

This study demonstrated the feasibility of developing a portable near-infrared (NIR) vein visualisation system using commercially available components and real-time image processing. The developed prototype successfully visualised superficial veins in different anatomical regions and among participants with different skin pigmentation conditions, demonstrating its potential as an aid for venipuncture procedures in clinical settings. Its compact design and relatively simple hardware configuration offer a practical and potentially cost-effective alternative to more expensive commercial vein visualisation devices. Future work will focus on integrating a Raspberry Pi NoIR camera, exploring advanced image-processing techniques, and incorporating artificial intelligence to improve vein visibility and overall system performance.

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Conflict of interest. Nil

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