Unique Contactless Device to Detect Veins and Heart Rate

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Abstract. Intravenous treatment has become a common platform to administer fluids into the bloodstream that can address various problems like dehydration, skin burns etc. Venipuncture is not easy on everyone as the patients can be anyone from infants to old age, physically unstable to abnormal candidates. Also, it is difficult to trace a vein in obese and dark people. Heart rate is a crucial measure of the cardiovascular state of humans. To overcome all these problems, a state-of-the-art vein viewer is developed to locate a vein in any part of the human body and also to measure heart rate. The vein finder with certain modifications in its design can be made into a small, portable, handy, inexpensive device with a simple and organized circuit. Generally, electronic, optical sensors or skin-contact instruments are used to calculate heart rate. Our objective is to compute the heart rate of a person by detecting the changes in facial color. Since the blood flow alters the skin color, these variations help in identifying heart rate. Near Infrared Red 0.5W LEDs are used based on the NIR spectrum absorption and scattering properties of veins, skin and processed the image in the studies. This procedure has an immense possibility to enhance telemedicine, health of a person and multiple applications where real-time physiological understanding is required. The design is simple, inexpensive and can be easily operated by anyone with a computer, which eliminates the need for technical skills.

Keywords: Intravenous treatment · venipuncture · cardiovascular state · Near-Infrared

1 Introduction

Intravenous therapy (IV) is one of the most common methods to administer drugs into the human body. There are nearly 7 billion venipuncture related procedures followed including blood draws, IV therapies, peripheral catheter insertions, etc. The severity of these cases lies from mild (general needle insertion) to high-level (drug administration into the deeper blood vessel like the pulmonary artery or aorta using a catheter). Proper vein access in these situations is of utmost importance. It is an essential sign to determine

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one's physiological condition. Veins are located 0–3 mm deep (in adults) inside the skin in the lowest layer of the epidermis. Their lumen is thinner to arteries and they carry deoxygenated blood except for the pulmonary vein [1]. They are very thin and have hair like in neonates and pediatrics. The location and access of these veins is difficult in some while it is easy in others. The vein access changes from person to person based on their skin tone, age, appearance, health conditions, etc. The device is designed to visualize veins in real-time. This device has a very simple circuit and works on the principle of NIR spectrum absorption and scattering properties of veins and skin. This can help to easily locate them and treat the person without causing much pain and trauma. The output can also be further processed for future uses.

Heart rate can be defined as the number of beats per minute. It is an important physiological parameter in the cardiovascular analysis of a living being. It gives the mental state of a person as heart rate can fluctuate based upon the person's state - anger, fear, anxiety and so on. It is an important parameter in the diagnosis of different cardiovascular diseases like tachycardia, bradycardia, etc. The traditional methodology adopted for the measurement of the heart rate is mostly a contact based one and it becomes troublesome if it requires continuous monitoring. It should be carried out under certain predefined conditions. This device overcame the challenge of invasive based diagnosis of heart rate by capturing the photos which can be processed in OpenCV using Python programming language.

2 Literature Survey

Venipuncture is one of the most common methods being used after oral ingestion for drug administration. This process of infusion is simple yet complex. Simple once the needle is fixated and complex in identification of the apt vein site. From a wide range of patients, the vein detection becomes complex in neonates, pediatrics and old. Also moles, burnt skin, transcutaneous fat, wrinkles, edema, etc. can become a greater obstacle for vein access. A vein finder is a solution that can help to trace the vein in most of these cases. The idea of developing the hardware circuit was formulated using the reference article of "A Low Cost Vein Detection System Using Integrable Mobile Camera Devices" [2]. "Peripheral intravenous cannulation with support of infrared laser vein viewing system in preoperative settings in pediatric patients" was used to analyze the circuit and the issues that can occur during the demonstration [3]. After the acquisition of the image, using algorithms for noise filtering and morphological operations to emphasize the region of interest in Matlab gives enhanced images of veins [4, 5]. Researchers in vein detection [6–11] had satisfactory results for either in capturing the image or processing regardless of the different data sizes, methods used. Because of the sole interest in vein detection and heart rate monitoring and its ability to give effective values, having through many websites and many review papers helped us in knowing the working principle of measuring heart rate. Besides many books and websites that have the content regarding the non-contact method of heart rate monitoring. Opting for a low cost way to track the heart rate in real-time continuously using OpenCV – Python programming, it seemed straightforward to try by considering these technologies [12–15].

3 Methodology

Understanding the importance of vein detection and heart rate monitoring in many of the clinical procedures which are vital and the need for non-contact methods of diagnosis and treatment in the recent deadly pandemic, it opened the door for a portable, simple, non-contact method of determining vein site detection and heart rate. It uses a regular PC with a small handheld device to collect the data and display the results in the most precise manner. The steps for processing of both the Vein Detection and Heart Rate are discussed in Fig. 1.

Hardware - The main principle is the optical property of blood. The veins in the human body carry deoxygenated blood except the pulmonary vein. Blood is a combination of hemoglobin and oxygen while the deoxygenated blood has less concentration of oxygen. The deoxygenated blood absorbs some part of the near Infrared light when focused on it and disperses the remaining. While oxygenated blood absorbs most of the light, scattering a minimal amount of light. This property enables one to view veins when they are focused to the NIR light source. This is also a property that differentiates oxygenated blood from deoxygenated blood. Also the veins are thin compared to arteries and are located near the periphery of the skin unlike arteries. This property helps one to view veins in real-time with the naked eye at the same time they can be photographed and analyzed in the software for further usage. This is also applicable to heart rate monitoring. The human heart pumps a certain volume of blood for every pulse. This volume may change from person to person based on their state of mind, age, physiological condition, etc. This change in blood volume generates a modulation in

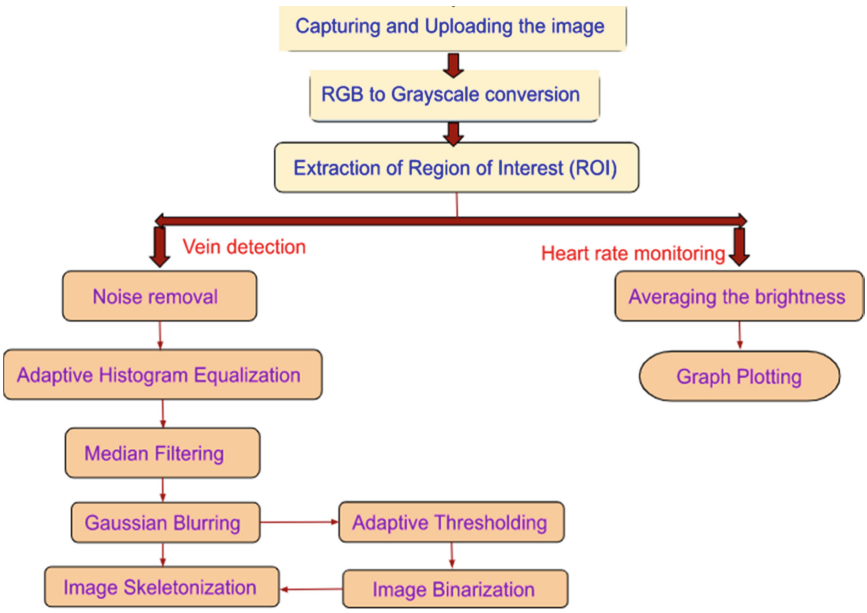

Fig. 1. Flowchart of the methodology

light reflectance when subjected to a NIR light source. The images of the light reflected from the light source are captured and are processed using the software.

A simple circuit consisting of Near Infrared Red LEDs (0.5W power) placed in a rectangular fashion along with a battery and a switch is designed. The light source was covered with filter paper to avoid the dispersion of light. When the circuit is switched on and focused on any part of the body, it could help one to trace the vein pattern in real-time as shown in Fig. 2. It can be further processed and analyzed using the software. The prototype device shown in Fig. 2 is tested on many subjects with varying age, gender and personalities and the results obtained are satisfactory.

Software - Visual studio software is used with Open source Computer Vision i.e. OpenCV using libraries such as Numpy and Python. It was programmed in such a way that it determines the heart rate of a person with 96% accuracy. The main principle behind it was the color variation of a person's skin with transition in their blood circulation. The software is programmed in such a way that when the photos are uploaded in the program module, it immediately performs the respective operations such as gray scaling, cropping, extraction, histogram equalization, filtering to give out the respective outputs of vein trace on skin and heart rate as a graph. The variation in the amount of light incident and reflected for every pulse is extracted, filtered, amplified, averaged and compared to give out the final output. The computation technique is quite simple here. The skin color varies for every heartbeat which is unrecognizable to the naked eye. While this color modulation can be detected by the image pixels. The program is designed in such a way that it selects the region of interest (ROI) from the image and the pixels that could identify the variation in skin color are averaged to give a peaked output frequency which is the heart rate of the person at that instance. The heart rate output is displayed in the form of a graph for every instance which is accurate. It will give an effective result when the subject is in a peaceful state of mind and the light source is focused from a distance ranging from 1 to 3 cm. At the same time the photos collected from the vein finder device are also processed in the same program which gives the output as a comparison of the

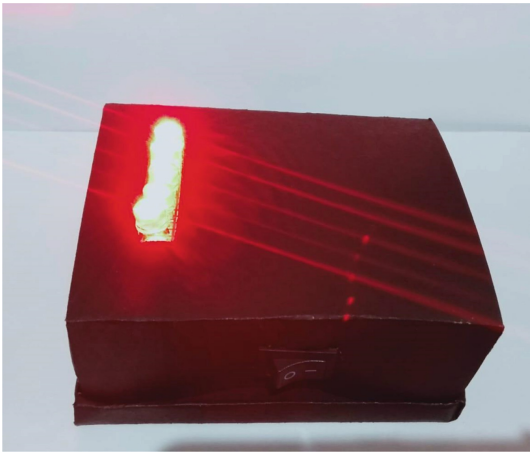

Fig. 2. Vein Viewer

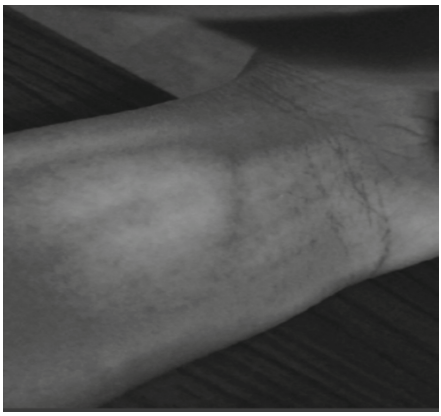

Fig. 3. Original image of the subject

original photo with that of a processed one that has a vein tracing. It helps to store the data and transmit it to other systems if needed. It is of utmost use for vein location to perform surgeries. It can also help for marking before any operations.

Different subjects of distinct age groups, genders, physiological characteristics, skin colors were tested using the device. The result thus obtained was compared with regular instrument results and it was mostly similar. In case of heart rate monitoring it was accurate and vein detection was also satisfactory though it was not in real-time.

4 Result and Conclusion

The designed system was successful in obtaining heart rate monitoring. We have collected the data from several subjects for testing the project. The subjects used for the analysis are of age 20–30. The subject was photographed under the influence of the NIR radiation using the prototype and portrayed in Fig. 3. The designed vein detection system was tested for verification purposes of different individuals and noise was removed (shown in Fig. 4) by image processing thus giving the clear vein pattern as shown in Fig. 5. The images taken are analyzed and output is given in the form of a graph that plots the heart rate of a person for the respective instance of time as shown in Fig. 6. The results obtained using these methods of heart rate monitoring and vein detection were fruitful and accurate. They can be analyzed and transmitted to other devices for further analysis. The overall results of the device were quite satisfactory, allowing a future scope of study in this area. The output from the device was almost accurate in comparison with the traditional devices. The device is a portable, hand-held device and is economical.

5 Future Scope

We intend to take it to another step by designing a small, handheld microcontroller based device that can obtain the images and videos in real-time, process them and display the output simultaneously by a projection of the data that can exactly give a 3D view of vein

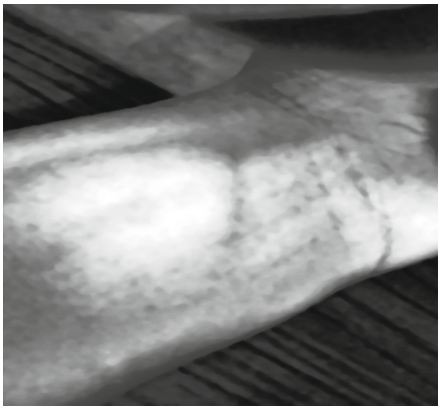

Fig. 4. Adaptive histogram equalization

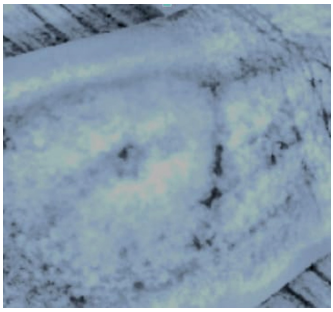

Fig. 5. Result of veins after processing

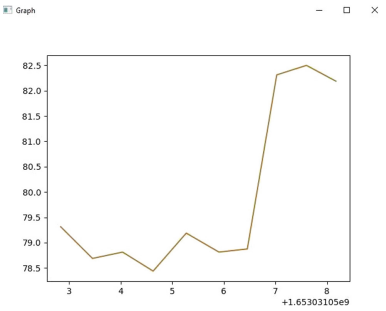

Fig. 6. Result of Heart Rate monitoring

location on the skin along with the vital physiological parameters of the person such as heart rate, spO2, temperature, etc. The whole output will consist of the 3D projection of the vein image of the person on the respective part with their softcopy record of physiological parameters. These details can be stored in the device and transmitted to other devices.

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