Design of vein finder with multi tuning wavelength using RGB LED

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Abstract. Detection of intra vena is very important technique in the medical clinic applications. For intravenous detection, some nurses usually have a mistake which can cause a pain or injured to the patient. When the nurses are headed with this problem, it becomes dangerous for the patient. To solve the problem, in this paper, vein finder with multi-tuning wavelength for intra vena detection is proposed and investigated. Vein finder is tested to various skin colour and body mass. The results show that vein finder was successfully designed with controllable wavelength in the range of 600-696 nm using RGB LED.

1. Introduction
Detection of intra vena is very important technique in the medical clinic applications. For intravenous detection, some nurses usually have a mistake which can cause a pain or injure to the patient. When the nurses face this problem, it becomes dangerous for the patient. Taking of blood sample at the veins is performed by nurses. Veins are not only used to take sample of blood, but also as a media of drugs delivery. Installation of a needle on a vein is required to match correctly and to provide comfort to the patient [1]. Installation of the needle fitting that is appropriate to the blood vessels is influenced by several factors including experience of the nurse and the patient's skin thickness to find the veins easily. Patients who are difficult to trace the vein called the Difficult Venous Access (DVA)[1]. Patient with DVA can be caused by fatness or young body likes baby and toddler.

The study conducted by The Infusion Nurses Society (INS) in the United States that the installation of the needle on the blood vessels is twice the maximum one nurse for every pair, if it is twice wrong it must call an experienced nurse to pair. The tools used to assist the performance of nurses is called vein finder. Vein finder prepared on lights of Light Emitting Diode (LED) with red colour that has a wavelength of 620 nm [2]. The working principle used by vein finder is by firing red light rays of LED with a wavelength of 620 nm on a patient's arm and then if there are blood vessels, the blood vessels will have a dark red colour or tending to black, while for other networks will remain red like colour LED. Research conducted by the vein finder [3], which focuses on the detection of the baby's blood vessels ranging in age from one month to two years. Resulted in a prototype tool using four pairs of super bright red LEDs with a wavelength of 620 nm and using the battery as a voltage source. However, the tool in this study is only able to detect the veins in patients aged one month to two years. Ade Pajar Pirdioanto (2013) developed a detection tool using LED type super flux red colour
that is believed to be brighter than LED super bright and fuzzy logic programming given in order to conserve battery power. This method is used in toddler. Based on several weaknesses in previous researches, the study of the vein finder needs to be developed further. Therefore, researchers design the vein finder to detect the veins which can be set according to the wavelength of the patient's condition. Veins detector with controllable wavelengths that can be set in accordance with the patient's condition will be very useful. Wavelength used by the colour of the LED output is generated. Vein Finder that is designed is also expected to be able to be used for all ages of patients. So it would be a useful tool used by medical personnel in hospitals, clinics or health centres in order to facilitate the installation of a needle on a vein, and also to be an alternative choice and technology development of vein finder.

2. Theory

2.1. The light characteristic on skin

The skin can be penetrated by light at specific wavelengths. The light is divided into three criteria in the breakout. Three criteria in the light of which light with a wavelength of 200-400 nm can only penetrate the epidermis skin layer, light with a wavelength of 400-600 nm can penetrate the dermis layer of the skin, whereas light with wavelengths of 600-700 nm can penetrate the skin subcutaneous tissue (Figure 1). Properties of the skin fired with the light reflect, scatter and absorb it.

![Figure 1. Wavelength of Light to Penetrate Skin [4]](image)

When the wavelength of visible light is 400-700 nm fired onto skin then some light will be absorbed, reflected and diffused into other parts of the skin. If the light wavelength range of 400-600 nm value then the light is merely distributed on the dermis only, whereas if the light wavelength of 600-700 nm, the light will spread and reach the subcutaneous layer of the skin in which there are blood vessels. Absorption, reflection and light transmission were fired can be seen in Figure 2. Colours absorbed by the skin will be forwarded to the subcutaneous layer where a vein is located. Vena will look black on the surface of the skin when exposed to light at these wavelengths. This is because haemoglobin in the blood absorbs the light so that the veins will be looks dark.
2.2. *Light absorption rate on haemoglobin*

In humans, there are approximately 4-6 liters of blood in which the blood is drawn up by 52-62% and the rest of the blood plasma of blood cells. Blood cells have their respective functions. Red blood cell as the largest content in blood cell has a function to carry oxygen to all parts of the body. To do this, the red blood cells have a component that is able to bind oxygen is *haemoglobin*. When the blood flows from the heart to the lungs, the *haemoglobin* binds oxygen going to be continued throughout the body (HbO2), while the return from the whole body to the heart, the *haemoglobin* is without oxygen (Hb).

![Figure 2. The Light Characteristic On Skin](image)

**Figure 2.** The Light Characteristic On Skin

![Figure 3. The absorption spectra of light in Hb and HbO2](image)

**Figure 3.** The absorption spectra of light in Hb and HbO2 [5]

In Figure 3, it can be seen the light spectrum absorption rate of haemoglobin carried by Zijlstra (2000) [14]. The picture show that the peak absorption of Hb and HbO2 is at wavelengths of 530 and 590 nanometers in a range of colours of green and yellow. These colours will be tested on heart rate calculation process to find the colour that best represents the heart rate.

2.3. *Light Emitting Diode (LED)*

LEDs can also be arranged for the colour output. These LEDs is called LED RGB (Red, Green, and Blue). RGB LED is designed to regulate the emergence of LED colour liking and is useful to use it because the LEDs can bring one of three colours, RGB LEDs have 3 basic colours used as a benchmark universal colour (primary colours). RGB LED is shown Figure 4.
The colours on the RGB LED can be changed based on the code numbers that are universal throughout the world. When one component has a stronger intensity, colour hue is close to primary (red, green, or blue), and when the two strongest components have the same intensity, the colour is the colour tone of secondary (cyan, magenta or yellow). Secondary colour formed by the sum of two primary colours has an equal intensity: cyan is green + blue, magenta red + blue, yellow and red + green. Each secondary colour is the complement of the primary colours. The combination of the three colours red, green, and blue in the right intensity will produce white. Their three component colours in RGB LED’s as well as a wide variety of colour combination, allowing us to try a wide variety of colours, wavelength, and power in the vein finder that is designed.

2.4. RGB colour model
RGB colour model is based on the concept of adding strong primary light that is Red, Green and Blue. No signal light waves are absorbed by our eyes or RGB (0, 0, 0). RGB colour wheels is shown Figure 5.

If we add the red light on the room, then the room will turn red for example RGB (255, 0, 0), all the objects in the room can only be seen as red. Enlightenment and the influence of light intensity in the RGB colour space can be seen in Figure 6.
2.5. Arduino
Arduino downloader software version 1.5, used in this study is an open source electronic kits designed specifically for enabling everyone to learn to develop electronic devices that can interact with a variety of sensors and controllers. The language used in Arduino programming language is C / C++. This software is used to program the LED lights that are in accordance with the results of the configuration specified by the user.

3. Methods

3.1. Equipment design
This research was performed by the combination of the two devices, namely hardware and software. Hardware is all electronic components used in the system. Designing appropriately for each of these components is very supportive of the design performance tool in this research. The design tool is preceded by making the hardware first. Consisting of LED driver circuit, LCD driver circuit and power supply. LED driver circuit is used as the activation function of the LED because this design uses RGB LED strip. RGB LED stands for Light Emitting Diode containing an array of colours Red, Green, and Blue. Power supply used is the battery. Circuit of RGB LED driver is shown on Figure 7.
Driver circuit using three transistors that act as an amplifier of each LED is represented by three feet of the RGB LED strip. Each leg on the foot base transistor is given by 1 kΩ resistor and used as input to the PWM pin on Arduino. Designing software is used as a regulator of the RGB LED colour that will be issued. The software used is 1.5 arduino IDE. IDE 1.5 is used as a writing arduino program in order to execute commands as well as the settings on the LCD display in accordance with the desired wavelengths. LED colour settings combined between each value of PWM. Then to make a bright red colour is required to adjust the other colours so that the red colour became dominant because the LED RGB LEDs have three primary colours of red, green and blue. Programming was written in IDE 1.5 software, then the program was downloaded into the microcontroller on the Arduino. Flowchart of program is shown in Figure 8.

![Flowchart](image)

**Figure 8. Flowchart**

### 3.2. Testing

The testing phase is used as a benchmark of the performance of a series designed hardware running appropriately or not appropriately. This test includes testing driver of RGB LED. Testing the value of the wavelength produced by RGB LED according to the reach of the needs was done by using a spectrometer. Testing of Wavelength of RGB LED will be varied based on the colour on each of its components measured in wavelengths. In this test the width of the grid is set at 0.02 mm. This wavelength will be calculated using the equation (1).

\[ d \sin \theta = n\lambda \]  

In testing of LED power phase, powermeter used in calculating the output power LED. Lit LED was to be measured in advance and placed parallel to powermeter. LED would then be moved away from the position powermeter with the displacement range of 0.5 cm. Data acquisition phase is used as an assessment of whether the design of the tool run well or not. Data retrieval was used in two circumstances, namely:

1. Colour LED wavelength was varied and then measured using a spectrometer.
2. LED output power was varied based on distance using powermeter.
3. Patients were varied then design tool used to detect a vein in the arm.

Data analysis was carried out in a visual way that is viewed by the eye sighting of the difference results from the design data retrieval tool designed. Patient used varied based on age, BMI scale, as well as skin colour.
4. Results

4.1. Wavelength testing
This research has successfully designed the vein finder wavelength that can be set as a detection tool of intravenous (IV). This device is designed to use multiple components and circuits including the power supply circuit, potentiometer circuit, LED circuit, LCD shield and Arduino Uno microcontroller.

| No. | Colour  | LED Configuration | Measured Wavelength (nm) |
|-----|---------|-------------------|--------------------------|
| 1   | Red 1   | (255,0,0)         | 696                      |
| 2   | Red 2   | (245,0,0)         | 693                      |
| 3   | Red 3   | (235,0,0)         | 682                      |
| 4   | Red 4   | (225,0,0)         | 660                      |
| 5   | Red 5   | (215,0,0)         | 663                      |
| 6   | Red 6   | (205,0,0)         | 647                      |
| 7   | Green   | (0,255,0)         | 516                      |
| 8   | Blue    | (0,0,255)         | 490                      |
| 9   | Orange  | (255,30,0)        | 604                      |
| 10  | Orange 1| (255,60,0)        | 569                      |
| 11  | Orange 2| (255,90,0)        | 599                      |
| 12  | Orange 3| (255,120,0)       | 606                      |
| 13  | Yellow 1| (255,210,0)       | 591                      |
| 14  | Yellow 2| (255,255,0)       | 567                      |
| 15  | Magenta | (255,0,255)       | 524                      |

Wavelength measurements were performed based on each order of colours seen in the telescope. As an example in Table 1, Red 1 configuration (255, 0, 0) wavelength measurements carried out as in general. But in colour measurement configuration with double or triple like orange with the configuration (255, 30, 0), measured wavelength was obtained from the average of each wavelength corresponding colour components.

According to Hossein (2014) in his article about the visible light spectroscopy, there is a range at a wavelength of a specific colour that is presented on the colour wheel. According to this colour wheel, red colour is contained in the wavelength range 630-750 nm. This is according to a test conducted on six types of red colour with a value between 205-255 bit configuration in which at least 205 configuration values have a range of wavelengths at 647 nm, while most configuration values of 255 have a wavelength of 696 nm. The other primary colours that were tested are green or blue. On the colour wheel the green wavelength is in the range of 480-560 nm, while the blue is in the range 430-480 nm. On spectrometry measurements, it was obtained that green colour wavelength had the range at 516 nm. This is in accordance with existing literature. As for the blue colour, it had a range of wavelengths at 490 nm. This is slightly different from the existing literature in which the blue colour is in the range 430-480 nm. This error can occur due to several factors including the vision is not focused during the measurement. It can be caused by human error, so that both the calculation of the angle and the light beam on the telescope sight errors may occur.

At the secondary colour measurements or merger of two primary colours. Measurement was done in the wavelength of the orange, yellow, and magenta. Orange colour is derived from mixing red and green. Orange colour in the colour wheel was contained in the wavelength range of 590-630 nm. This is in accordance with the measurements made. Where in orange 3 with the highest level of green colour on the configuration (255, 120, 0) got a wavelength in the range of 606 nm whereas the orange
with the lowest level of the green colour on the configuration (255, 30, 0) got a wavelength in the range of 604 nm. In the yellow colour is also obtained from mixing red and green, a colour wheel according to the wavelengths are in the range of 560-590 nm. This is in accordance with the measurements made in this research.

4.2. Results of Output Power LED Tested

In observing the LED circuit, then the measurement of the output power of the LED is done by using a power meter. These measurements were varied by LEDs on the power meter distance. The data obtained are presented in Table 2.

| Table 2. Comparison of Power to the Distance to Detect Wavelength |
|---------------|-----------------|-----------|-----------|
| No | Colour | Wavelength (nm) | Distance (cm) | Power (mW) |
|----|--------|-----------------|--------------|------------|
| 0.5| 1 | Red | 696 | 2.145 |
| 1 | 2.171 |
| 1.5| 1 | Red | 696 | 0.813 |
| 2 | 0.542 |
| 2.5| 1 | Red | 516 | 0.466 |
| 0.5 | 2.101 |
| 1 | 1.243 |
| 2 | Green | 516 | 0.873 |
| 1.5 | 0.613 |
| 2 | 0.531 |
| 2.5| 0.531 |
| 0.5 | 2.168 |
| 1 | 1.278 |
| 3 | Blue | 490 | 0.840 |
| 1.5 | 0.554 |
| 2 | 0.509 |
| 2.5| 0.509 |
| 0.5 | 1.662 |
| 1 | 1.051 |
| 4 | Red 2 | 693 | 0.750 |
| 1.5 | 0.566 |
| 2 | 0.485 |
| 2.5| 0.485 |
| 0.5 | 1.993 |
| 1 | 1.117 |
| 5 | Red 3 | 682 | 0.786 |
| 1.5 | 0.540 |
| 2 | 0.496 |
| 2.5| 0.496 |
| 0.5 | 1.963 |
| 1 | 1.153 |
| 6 | Red 4 | 660 | 0.749 |
| 1.5 | 0.499 |
| 2 | 0.462 |
| 2.5| 0.462 |
| 0.5 | 1.867 |
| 1 | 1.105 |
| 7 | Red 5 | 663 | 0.736 |
| 1.5 | 0.484 |
| 2 | 0.441 |
| 2.5| 0.441 |
| 0.5 | 1.813 |
| 1 | 1.082 |
| 8 | Red 6 | 647 | 0.717 |
| 1.5 | 0.469 |
| No | Colour      | Wavelength (nm) | Distance (cm) | Power (mW) |
|----|-------------|----------------|---------------|------------|
| 9  | Orange      | 604            | 2.5           | 0.431      |
|    |             |                | 0.5           | 2.545      |
|    |             |                | 1             | 1.506      |
|    |             |                | 2             | 0.694      |
|    |             |                | 2.5           | 0.598      |
|    |             |                | 0.5           | 2.8        |
|    |             |                | 1             | 1.669      |
| 10 | Orange 1    | 569            | 1.5           | 1.102      |
|    |             |                | 2             | 0.775      |
|    |             |                | 2.5           | 0.663      |
|    |             |                | 0.5           | 3.568      |
|    |             |                | 1             | 1.667      |
| 11 | Orange 2    | 599            | 1.5           | 1.207      |
|    |             |                | 2             | 0.784      |
|    |             |                | 2.5           | 0.668      |
|    |             |                | 0.5           | 3.336      |
|    |             |                | 1             | 2.004      |
| 12 | Orange 3    | 606            | 1.5           | 1.327      |
|    |             |                | 2             | 0.929      |
|    |             |                | 2.5           | 0.792      |
|    |             |                | 0.5           | 3.599      |
|    |             |                | 1             | 2.071      |
| 13 | Yellow 1    | 591            | 1.5           | 1.380      |
|    |             |                | 2             | 0.878      |
|    |             |                | 2.5           | 0.817      |
|    |             |                | 0.5           | 3.153      |
|    |             |                | 1             | 1.853      |
| 14 | Yellow 2    | 567            | 1.5           | 1.233      |
|    |             |                | 2             | 0.861      |
|    |             |                | 2.5           | 0.736      |
|    |             |                | 0.5           | 4.458      |
|    |             |                | 1             | 2.566      |
| 15 | Magenta     | 524            | 1.5           | 1.668      |
|    |             |                | 2             | 1.154      |
|    |             |                | 2.5           | 0.988      |

From these measurements, it can be seen that the greater the distance from the LED power meter, the smaller the power also arrested. For example, the red one with a distance of 0.5 cm, LEDs was capable of emitting a power of 2,145 mW, while at a distance of 2.5 cm, the LED was only capable of emitting power of 0.466 mW.
As can be seen in Figure 9 of all colours have been tested, the power will be smaller if given the greater distance. This is possible because LEDs used have the properties of light spread, so if a given distance was farther then the power meter could only capture most of the power of the LED. In addition to distance, power measured is also influenced by the number of colours components. For example, the colour magenta, the power obtained at a distance of 0.5 cm is 4.458 mW. This value is much greater than the value of the power produced by the red and blue colour that is at 2.614 mW and 2.168 mW. This is because the magenta is an arrangement of red and blue colour components so as to form a magenta colour needs to be lit red and blue colour components in RGB LEDs. This is what causes the output power is greater than the magenta colour red or blue colour on the RGB LEDs.

4.3. Data analysis

The overall colours and configurations were tested first on one patient. This is done to look at the configuration of LEDs and a range of wavelengths that can penetrate the skin. In the configuration of LEDs (0, 0, 255) in blue and a wavelength of 490 nm, the light emitted by the LED is obtained not able to penetrate the skin of the patient. In the configuration of LEDs (0, 255, 0) with a green colour and a wavelength of 516 nm, it has been obtained image that may represent veins. Arising shadow is also found in each secondary colour configuration with a combination of red and blue as well as red-green. As an example, the configuration of the LED (255, 255, 0) is on yellow 2 and a wavelength of 567. In this configuration, the shadow is much evident when compared with the colour green. On the surface of the skin, red colour looks more dominating than the green colour. In red colour with LED sequential configuration of (205, 0, 0) to (255,0,0) with a wavelength of 647-696nm. The blood vessels will be more clearly seen as increasing the size of the wavelength. In the configuration of LEDs (205, 0, 0), Red 6 still looks a little bit shadow that does not represent the veins. While the configuration of the LED (255, 0, 0), the veins can be seen clearly.

The level of depth of epidermis of the skin in adults is in the range of 0-3 mm, where the veins are in the lowest layer of the epidermis of the skin [7]. This is consistent with the research that has been done. In blue colour with a wavelength of 490 nm, the light can not penetrate through the veins. While
the red colour with a wavelength of 647-696 nm, the light that is able to reach the veins with the best result was at a wavelength of 696 nm.

In the combined results of a secondary colour between red and blue as well as red-green, the LED light can penetrate the skin to the surface of the vein. This is possible because on any combination of colours, the configuration is done on the red always at the maximum level of colour (255). Only with the addition of the other colours on the configuration, the appearance of the veins will be slightly reduced or interrupted with other skin components that were detected. After knowing the level of translucency of colour on the skin, vein finder was designed to be tested on 10 people patient with BMI levels and skin colour is different. List of patients tested along with BMI and skin colour respectively is shown on Table 3.

| No | Patient number | Age (years old) | Weight (kg) | Height (cm) | BMI | BMI Information | Skin Colour | Result |
|----|----------------|-----------------|-------------|-------------|-----|-----------------|-------------|--------|
| 1. | 1              | 24              | 80          | 164         | 29.74 | Fat             | Brown black| Visible|
| 2. | 2              | 25              | 77          | 175         | 25.14 | Fat             | Yellow brown| Visible|
| 3. | 3              | 23              | 69          | 167         | 24.74 | Normal          | Brown Black | Visible|
| 4. | 4              | 23              | 79          | 173         | 26.4  | Fat             | Yellow brown| Visible|
| 5. | 5              | 24              | 75          | 155         | 31.22 | Level 1 Obesity| Yellow brown| Visible|
| 6. | 6              | 23              | 95          | 178         | 29.98 | Fat             | White red | Visible|
| 7. | 7              | 26              | 71          | 165         | 26.08 | Fat             | Fat Level 1 Obesity| Visible|
| 8. | 8              | 4               | 18          | 75          | 32    | Fat             | Brown | Visible|
| 9. | 9              | 63              | 75          | 161         | 28.93 | Fat             | Brown | Visible|
| 10. | 10             | 40              | 65          | 168         | 23.03 | Fat             | White | Visible|

From the results of tests on 10 patients, it is obtained that the whole patient visible blood vessels veins with BMI levels were different from each patient or a different skin colour. As an example, patient number 4, 23 years old with a BMI level of 26.4 is classified as fat. Figure 10(a) shows the results of the current documentation of measurement. Figure 10(b) is the results of the binary image processing software. The binary image here is intended to clarify the results of the appearance of the veins on documentation.

Figure 10. Appearance of Veins of Patient Number 4 in (a) The Colour Image (b) Binary Image
5. Conclusions

5.1. Conclusions
Based on these results we can conclude that:
the vein finder was successfully designed with controllable wavelength in the range of 600-696 nm
using RGB LED. Vein finder was able to be used to detect veins of 10 patients with different age,
IMT and skin colour.

5.2. Suggestions
In designing of vein finder, LED circuit should add a lens to focusing the light. A stable and longer
lifetime power supply is also a need for further research.

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