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Design of Portable Optical Vein Finder

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Annotation: Several people are unlucky with veins that are hard to stick. Some of them just have small veins that are hard to feel for and hard to get a needle into, other fat people tend to have their veins buried deeper and are thus harder to find. In this case, phlebotomists need several tries to find the vein and stick it properly, wasting their time and effort, and creating pain to these patients.

This project aims to build a portable vein finder, that uses visible and near infrared radiations (NIR)light. The system will help the phlebotomists to explore the vein easily by applying a visible and NIR wavelengths on the patient's arm.it will use processing unit to control light intensity to provide the phlebotomists with the place of the patients vein within a one seconds. Hence, reducing the patient pain, and saving phlebotomists effort and time.

Introduction

Several medical imaging purposes are based on using near-infrared (NIR) window , such as spectroscopy and tomography. In the70s, visualization of peripheral blood vessels was explored

by several researchers for the first time, using infrared) IR) photography or a TV infrascope, these methods did not allow real-time visualization.

More recently, due to technological developments, new techniques have become available to make real-time NIR imaging possible, mostly due to intension arrow band visible and NIR light sources (light emitting diodes, LEDs) and cameras with a high sensitivity for NIR light. The new methods of visualization of blood vessels were not immediately used to facilitate peripheral venous or arterial access, but for biometric identifications by vein patterns, monitoring of physiological parameters such as local blood flow and oxygenation. However, more recently, several researchers have explored the possibility of using visualization of blood vessels to facilitate peripheral venous or arterial access.

At the start of the research described in this thesis, only the Vein finder at that moment still a bulky device, and the Vascular Viewer were available, but rather expensive. Therefore, in this project the relatively low cost, vascular imaging system based on trans illumination of visible and NIR light.

1.1 Project idea description

During blood draw in the hospitals and medical clinics, sometime phlebotomists cannot find properly the location of veins for dark skin and obesity patients. The idea of this project is to design a vascular access medical device that can help phlebotomists in finding the optimal venipuncture site and avoid potential complications. The hemoglobin in our blood absorbs IR light. A vein finder that shines IR light on skin causes veins to become much more visible to the naked eye. IR is at the red of the color spectrum so we will design device include red lamps as well as IR to make the light visible.

we well designed affordable and very portable device, where it’s good to use on both children and adult. A small simulation of the original device by shedding wavelengths near IR on the patient's arm, to operate it has only an on/off switch and runs off a AA battery , the batteries are predicted to last between (5_8) hours of continuous use, when they begin to get low, the alarm on analog control it blinking.

1.2 Main objective

- Design of a portable medical device from the detection of veins in the for normal people arms.
- Help the medical staff find the vein easily when blood samples are drawn especially for people with dark to skin and obese.
- Reduce the patient’s pain and side effects resulting from the traditional search on the vein.
- Provide the time and effort of medical staff lost in conventional vein search.

1.3 List of abbreviation

Table 1.1: List of Abbreviation

Abbreviation	Full Meaning
VV	Vein Viewer
NIR	Near Infrared Red
LED	Light Emitting Diodes
IR	Infrared
V	Voltage
nm	Nano meter
UV	Ultra violet
DC	Direct current

1.4 Budget

In this section a list of estimated cost of the project components is presented that are uses in design device, this cost shown in table(1.2).

Type	Price	Quantity
Arduino Nano	**20$**	**1**
LEDsCR5111A-WY	**15$**	**12**
LED690-03AU	**15$**	**12**
LEDs ELD-650	**15$**	**12**
Datec-Pocket-Box	**20$**	**1**
RESISTOR	**5$**	**36**
Total price	**$ 110**	

Table 1.2: project Components Cost.

1.5 Time schedule

In this part show plan for the work project tasks and time schedule in the semester, this time plan shown in the table (1.3) and table (1.4)

Weeks Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collect Information															
Basic Design															
Specification Design															
Documentation															

Table 1.3: Timing Schedule of the First Semester.

Weeks / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Full Designing																
Purchasing the components																
System Implementation																
System analysis																
Documentation																

Table 1.4: Timing Schedule of the Second Semester.

Chapter 2

Anatomical and Physiological of the Skin

Skin is the outermost tissue of the body and the largest organ in terms of both weight and surface area. It has an area of approximately 16,000cm2 for an adult and represents about 8% of the body weight. skin has a very complex structure that consists of many components as shown in fig(2.1) . Cells, fibers and other components make up several different layers that give skin a multi-layered structure. Veins, capillaries and nerves form vast networks inside this structure. In addition ,hairs stick out from the inside of skin. Numerous fine hair are scattered over the surface of skin.

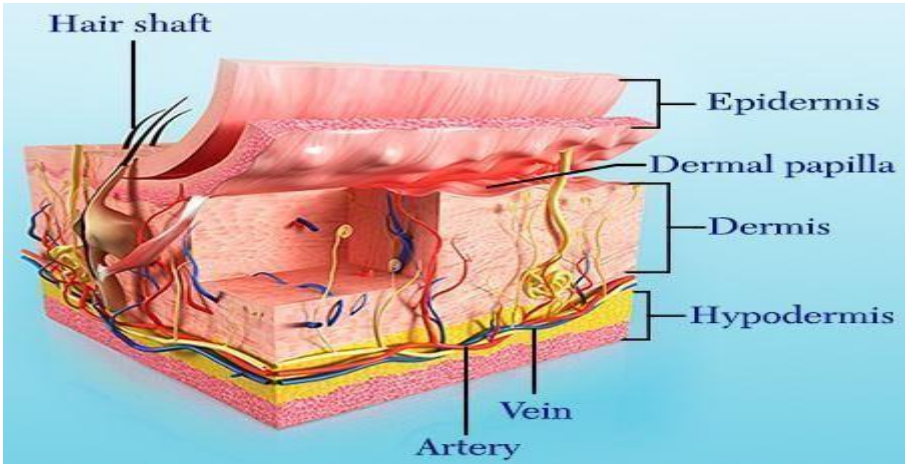

Fig 2.1: sectional schematic diagram of skin[1]

1.2 Skin anatomy

The largest organ of the body is the skin, which is multilayered with its three main layers being epidermis, dermis and the subcutaneous layer, also called the hypodermis. Fig

(2.2) shows the section of skin. The epidermis is the outermost layer and does not contain any blood vessels. It allows light to pass through it owing to its presence in the superficial section of skin. The middle layer known as the dermis contains capillaries, glands and hair

follicles. Diffusion takes place between the dermis and epidermis to provide nutrient supply. The hypodermis lying above the muscle and bone is the lowermost layer in the skin consisting of fat cells, veins, arteries and nerves. The amount of subcutaneous fat in this layer determines the penetration of light into tissue beneath it [2]. Children possess skin of lesser thickness as compared to adults. The depth of epidermis ranges from 0.027 – 0.15mm and that of dermis ranges from 0.6 – 3mm. The hypodermal thickness can be between 0 – 3mm with the maximum in the abdomen [3].

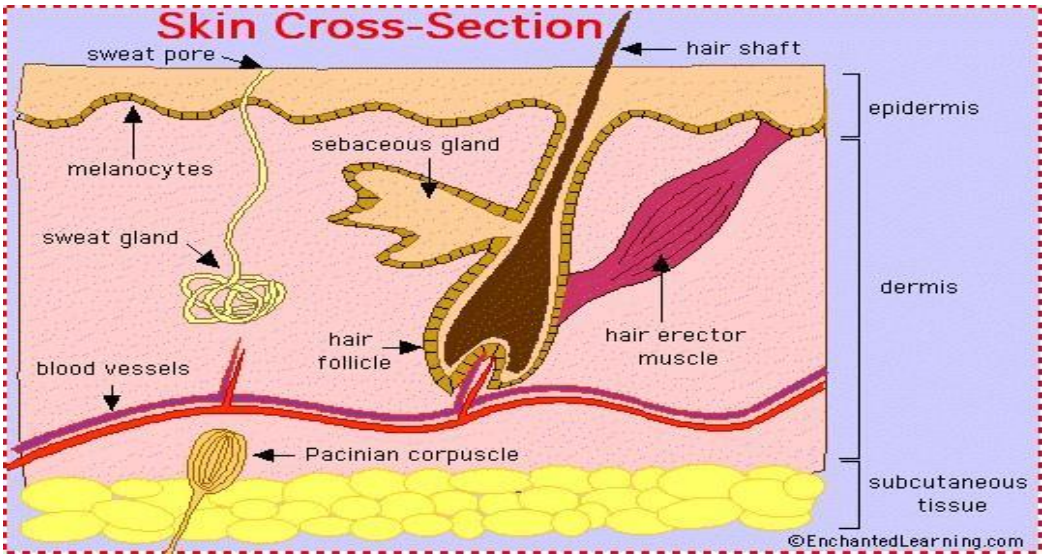

Fig 2.2: Section of human skin.[4]

2.1.1 Epidermis

The epidermis is the outer layer of skin. The thickness of the epidermis varies in different types of skin. It is the thinnest on the eyelids at 0.05 mm and the thickest on the palms and soles at 1.5 mm. [5]

The epidermis contains 5 layers. The layers are named from bottom to top as shown in figures (2.3):

- ✓ Stratum Basale
- ✓ Stratum Spinosum
- ✓ Stratum Granulosum
- ✓ Stratum Licidum
- ✓ Stratum Corneum.

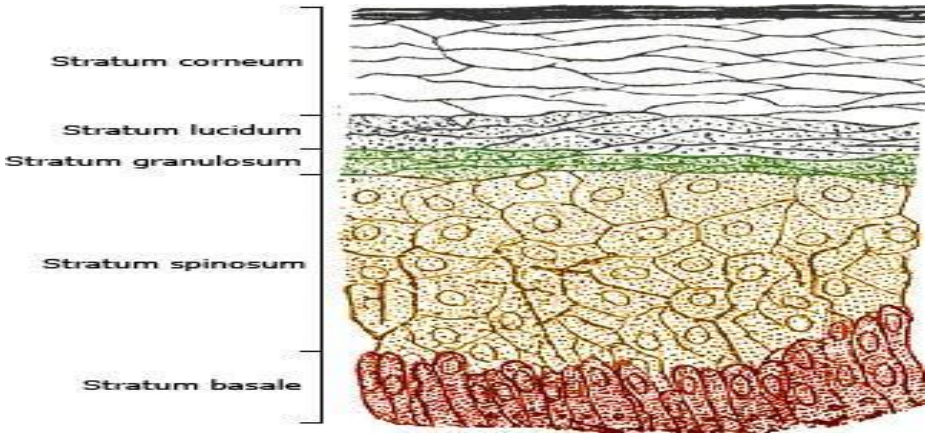

Fig 2.3: The Epidermis Layers[6]

2.1.2 Dermis

The dermis also varies in thickness depending on the location of the skin,as shown in figure(2.4). It is 0.3 mm on the eyelid and 3.0 mm on the back. The types of dermis are: [7]

- ✓ Collagen
- ✓ Elastic tissue
- ✓ Reticular fibers

The dermis have three layers , this layers is: two layers of the dermis are the papillary and reticular layers , the upper papillary layer, contains a thin arrangement of collagen fibers and the lower reticular layer, is thicker and made of thick collagen fibers that are arranged parallel to the surface of the skin.

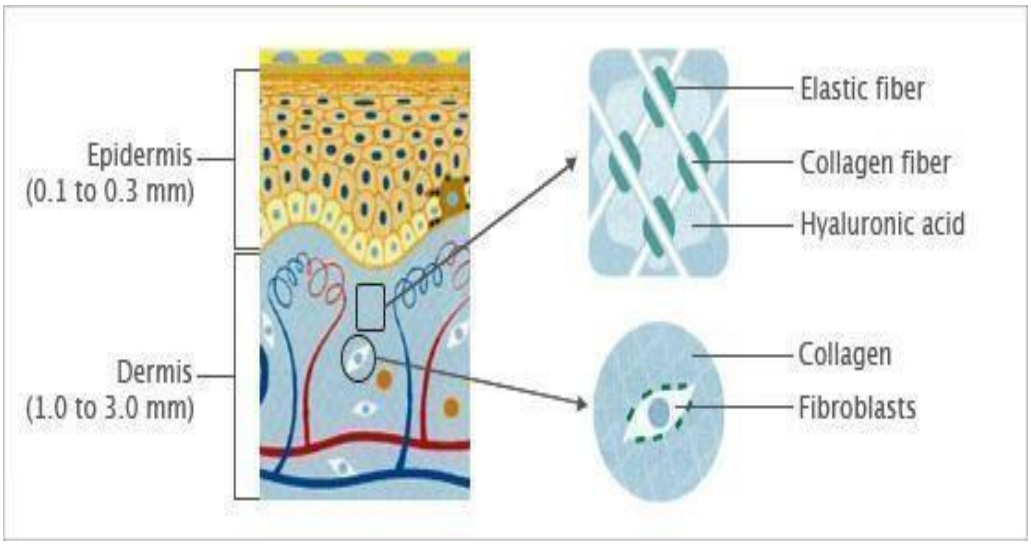

Fig 2.4: Dermis[8]

2.1.3 Subcutaneous tissue

Is a layer of fat and connective tissue that houses larger blood vessels and nerves. This layer is important is the regulation of temperature of the skin itself and the body. The size of this layer varies throughout the body and from person to person.The skin is a complicated structure with many functions. If any of the structures in the skin are not working properly, a rash or abnormal sensation is the result. The whole specialty of dermatology is devoted to understanding the skin, what can go wrong, and what to do if something does go wrong. [9]

2.2 Skin physiology

The skin performs five main functions:

1. Regulation of body temperature
2. Protection
3. Sensation
4. Excretion
5. Synthesis of vitamin D

2.3 Skin optics

Studying the phenomena of light transport in tissue will give a better understanding of the working of the Vein finder system. Fig(2.5) depicts the scattering of light in human tissue. The light beam that is incident on the skin undergoes absorption, scattering and reflection by the various layers of tissue at different depths. The characteristics of light propagation differ with respect to each layer in the skin. The reflection of light from the skin surface is called specular reflection. Light that is specularly reflected does not permit light to propagate through internal tissue and can thus add glare to a vein image.

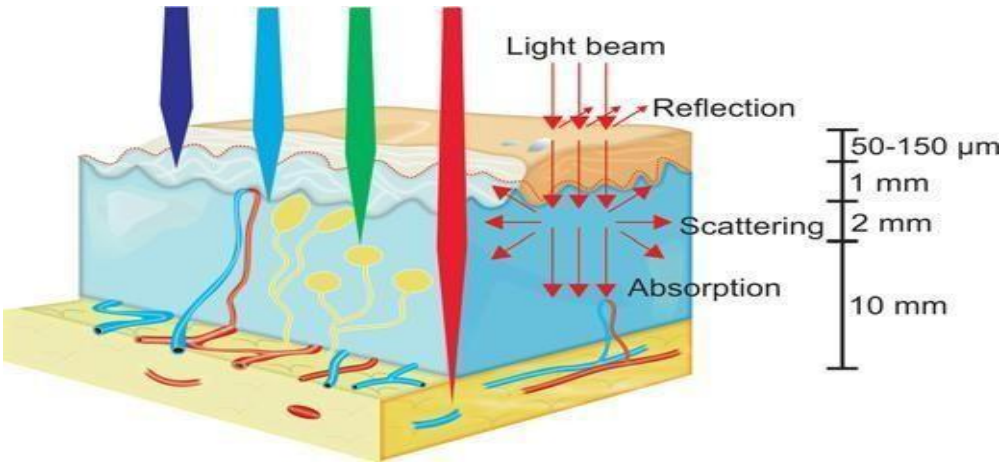

Fig 2.5: Propagation of light in various tissues.[10]

A three-compartment model of skin is considered which consists of epidermis, dermis and subcutaneous layer. The epidermal layer absorbs some light and transmits light into the tissue layers beneath it after scattering. A lot of scattering occurs in the dermis before it propagates to the hypodermal layer while a part of the light is absorbed. Fat scatters a major portion of light and absorbs very little. Some of the light reaching blood in the vessels is absorbed by the hemoglobin present in it, while some is scattered mostly in the forward direction due to

the large size of the red blood cells. It has been reported that the blood in the veins is dominated by deoxy-hemoglobin with the oxy-hemoglobin content concentration around 47% while that in the arteries contains more oxy-hemoglobin (90% – 95%) [2, 5]. Both types of hemoglobin possess different light absorption properties as shown in Fig (2.6) [11]. Both types exhibit almost the same absorption characteristics till the wavelength of 600nm. It can be understood that the absorption

of light by veins is higher than that by arteries between the wavelengths of 600nm – 800nm. The curve falls rapidly for the deoxyhemoglobin while it rises a little and then falls for the oxy-hemoglobin.

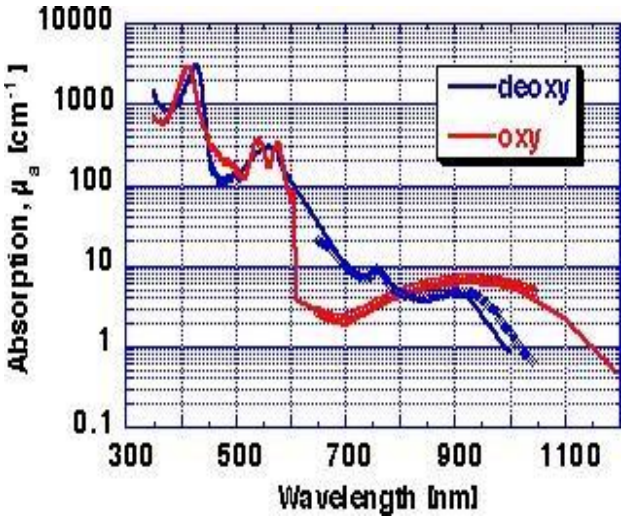

Fig 2.6: Absorption of oxy and deoxy-hemoglobin of whole blood.[12]

Light at different wavelengths reaches different depths when it travels through tissue as seen in Fig (2.7). The bars in Fig (2.7) indicate the extent of transmission of light in all

layers of the skin at various wavelengths. Visible light wavelengths range from 400nm – 700nm while infrared(IR) wavelengths range from 700nm – 1000 nm. Light at wavelengths between 300nm and 400nm reach only the epidermal and dermal sections of the skin which do not contain any veins. Light at near-infrared(NIR) wavelengths (700 – 1000nm) is less absorbed by other tissue and reaches the blood vessels in the subcutaneous tissue. The VV utilizes this phenomenon to view veins which cannot be visualized in visible light. The principle of working of the VV system is based on tissue-light interaction in the body. The clinical utility of the VV system determined from prior studies on pediatric subjects is also discussed.

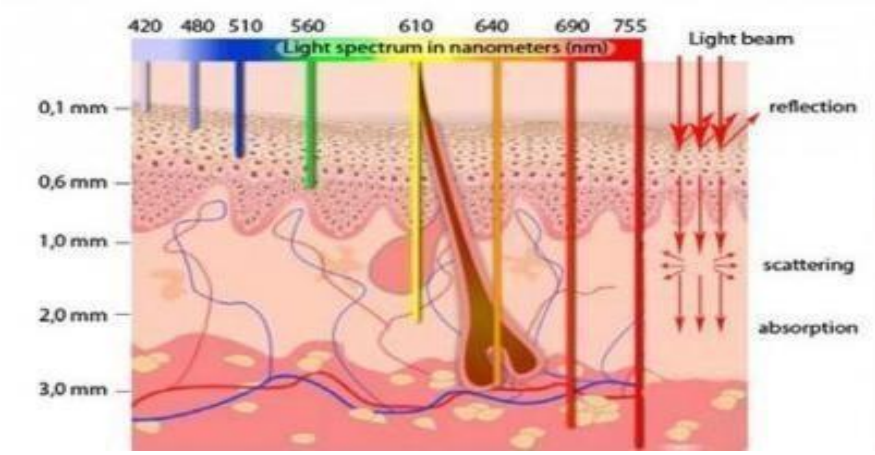

Fig 2.7: Light propagation at different wavelengths in tissue.[13

Chapter 3 Interaction of Near Infrared with Tissue in Vein Finder

3.1 Electromagnetic spectrum

Wavelength**,** distance between corresponding points of two consecutive waves.

Corresponding points‖ refers to two points or particles in the same phase—i.e., points that have completed identical fractions of their periodic motion. Usually, in transverse waves (waves with points oscillating at right angles to the direction of their advance), wavelength is measured from crest to crest or from trough to trough; in longitudinal waves (waves with points vibrating in the same direction as their advance), it is measured from compression to compression or from rarefaction to rarefaction. Wavelength is usually denoted by the Greek letter lambda (λ); it is equal to the speed (v) of a wave train in a medium divided by its frequancy (*f*): $\lambda = v/f$.

The order of colors in light, arranged from shortest wavelength to longest, is called the visible spectrum of light. The figure(3.1) shows light's visible spectrum, which runs from violet to red. You might recognize the spectrum as the order of colors in a rainbow.

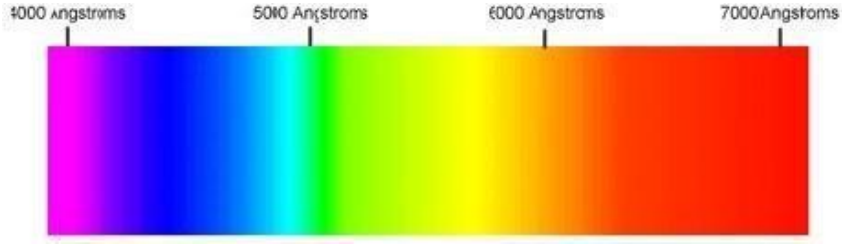

Figure 3.1: light's visible spectrum [13]

But light waves can also have wavelengths lower or higher than the wavelengths in the visible spectrum, and many familiar types of radiation are just light waves with other wavelengths. Ultraviolet light and x-rays have wavelengths shorter than violet light, and infrared (heat) and radio waves have wavelengths longer than red light.

The full range of wavelengths for light is called the "electromagnetic spectrum." The figure(3.2) show which wavelength ranges in the electromagnetic spectrum correspond to light types.

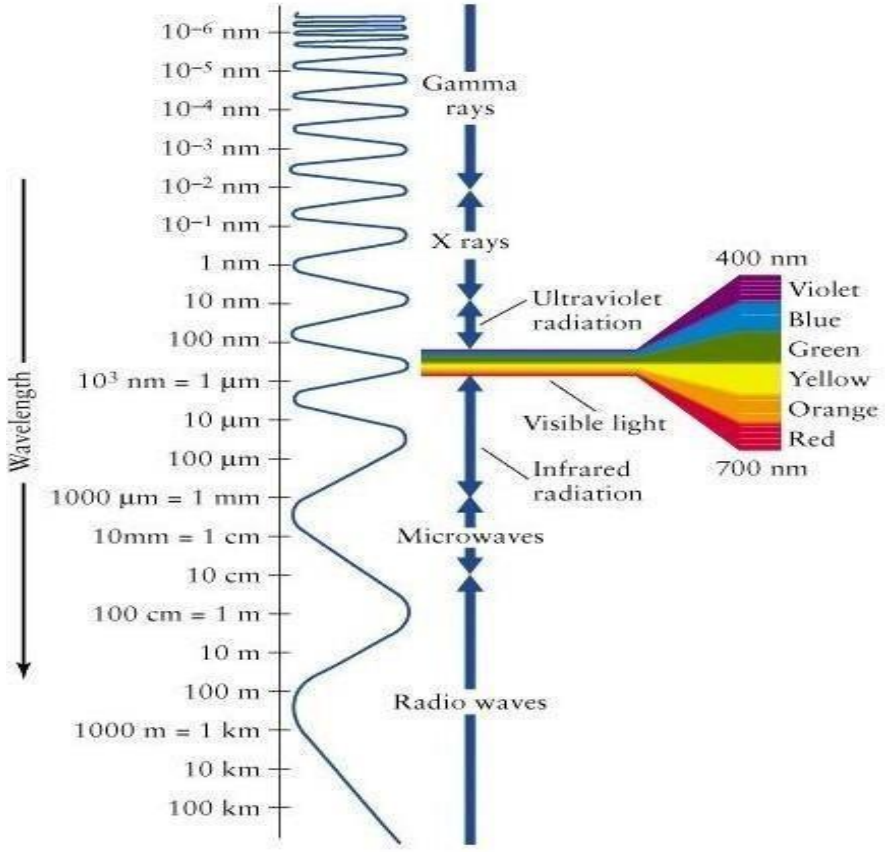

Figure 3.2: wavelength ranges in the electromagnetic spectrum correspond to which types of light.[14]

3.2 Near-Infrared Light

Near-infrared (NIR) light is electromagnetic radiation with a longer wavelength (from 650nm up to 3000nm) than visible light (350–660)nm, as depicted in figure (3.3) which shows ultraviolet (UV) light, visible (VIS) lightand near-infrared (NIR) light. The near- infrared window is shown in grey). It is invisible to the human eye.

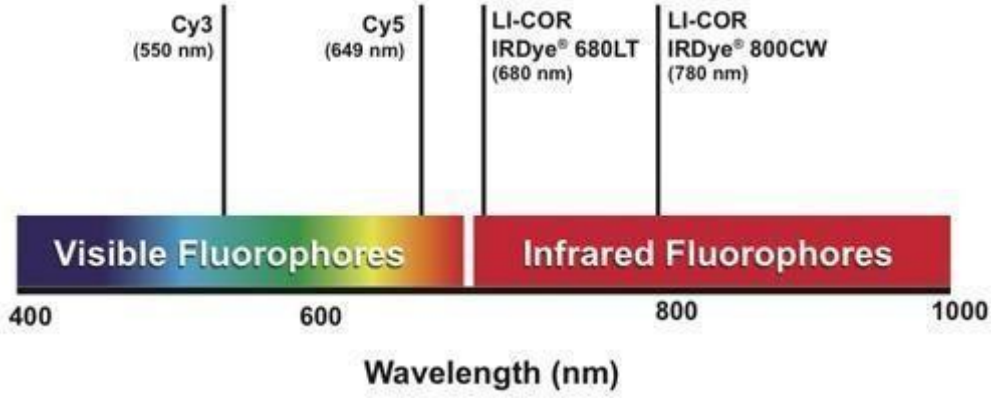

Figure 3.3: Part of the electromagnetic spectrum [15]

Infrared waves are longer than those of visible light, just beyond the red end of the visible spectrum. Infrared (IR) falls in the range of the (EM) spectrum between microwaves and visible light. It has frequencies from about 3 GHz up to about 400 THz and wavelengths of about 30 centimeters (12 inches) to 740 nanometers (0.00003 inches).

3.2.1 Visible light and near-Infrared Light interaction with biological tissues

Behavior of (near-infrared) light in tissue is characterized mainly by two phenomena:

absorption and scattering as shown in figure(3.4).A light particle(photon)can be absorbed by molecules known as chromophores during interaction with tissue the photon can also be redirected during interaction with molecules, which is called scattering. The amount of absorption and scattering is wavelength and tissue (chromophore) dependent and is determined respectively by the absorption coefficient μa and the scattering coefficient μs[1].There is a preferred direction of scattering depending on wavelength and size of the chromophores, described by anisotropy factor 1 (mean cosine scattering angle)[16].For the

amount of forward scattering, the reduced scattering coefficient μ0 s is used, which is defined as μs(1−g).Figure(3.4) show saschematic view of an absorption event and a scattering event when a photon interacts with a molecule.

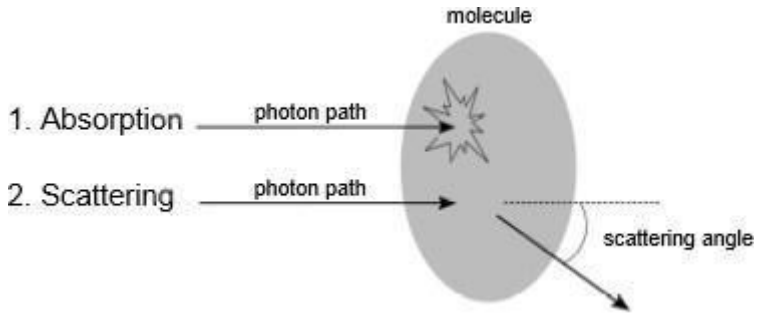

Figure 3. 4: Schematic view of an absorption event and a scattering event [16]

Blood vessels are covered by a layer of subcutaneous fat, followed by the dermis and finally the epidermis. The epidermis is typically 0.1mm thick, while the dermis is about 0.5mm to a few millimeters thick, depending on anatomical location and patient characteristics. The blood vessels are buried in the subcutaneous fat at a depth of up to a few millimeters. The main chromophores are melanin (’brown’ pigment) and lipids in the epidermis, and hemoglobin (in the red blood cells),

water and lipids in the dermis and subcutaneous fat[17]. Absorption by most of these chromophores is far less in the near- infrared part as compared to the visible part of the spectrum. However, absorption by water typically starts to increase above 900nm as shown in figure (3.5). The scattering behavior of photons in tissue is usually described by Mie and Rayleigh scattering. Rayleigh scattering is scattering by particles smaller than a tenth of the wavelength (such as cell organelles) and is isotropic, while Mie scattering is scattering by particles larger than the wavelength (such as collagen fibers) and is mainly forwardly orientated [18]. The amount of Mie and Rayleigh scattering is inversely related to wavelength, but Rayleigh scattering decreases more rapidly. Mie scattering is dominant in the near infrared spectrum and therefore most relevant to the project purpose. The most important scatterers are collagen and fat in skin and hemoglobin in blood[17]. If scattering is much higher than absorption, which is the case in most types of tissue in the near-infrared spectrum,light becomes quickly isotropic, allowing for diff usion theory to be used to calculate light transport in tissue [19].

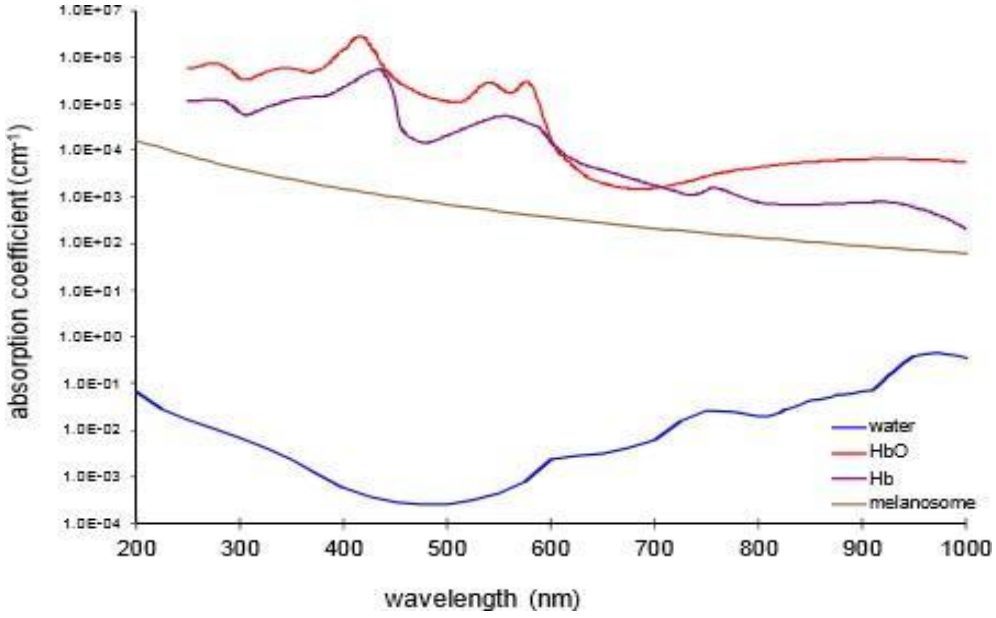

Figure 3.5: Absorption coefficient about wavelength[20]

The decreased absorption and scattering of chromophores,described above, leads to a wavelength region between 650 to 1100nm in which deep tissue penetration is possible as discussed in figure (3.3). At the low end of this region, absorption of hemoglobin and melanin and scattering are high, while at the high end absorption of water is increasing rapidly [21].The region in between is called the near-infrared window and enables visualization of blood vessels, since the concentration of hemoglobin in blood vessels is high enough to generate a large contrast between tissue and blood vessels.

3.2.2 Optimal wavelength for subsurface visualization of blood vessels

Blood vessels that are used for peripheral venous and arterial access are typically located up to a few millimeters below the skin surface. The blood vessels are embedded in a layer of subcutaneous adipose tissue, at a depth of 1 mm to several millimeters. On top, the epidermis (0:1mm) is situated, followed by the dermis (1 mm).

The main chromophores in epidermis, dermis and subcutaneous adipose tissue are melanin, blood (mostly hemoglobin), lipids and water. In the visible part of the spectrum, melanin and hemoglobin are highly absorptive, counteracting deep tissue penetration. In the Visible light and near infrared light part of the spectrum (600–880 nm), there is much less absorption by melanin and hemoglobin. However, above 900 nm, absorption of water is increasing,

again preventing deep tissue penetration. This creates a so-called ―window‖ between600 to 880 nm, where deep tissue penetration with light is possible [22]. Scattering of light by tissue is also

an important factor in characterizing the depth of tissue penetration. In the NIR region scattering is less than in the visible region, but it still causes a larger light attenuation than absorption in light-tissue interaction.

The NIR window can be used to penetrate skin and subcutaneous adipose tissue up to a depth of several centimeters. The absorption of NIR light by blood (hemoglobin) in the blood vessels is still sufficient to generate a high contrast between blood vessels and surrounding tissue, as can be seen in figure(3.6). A detailed description of the equations used to calculate transmission of light through tissue.

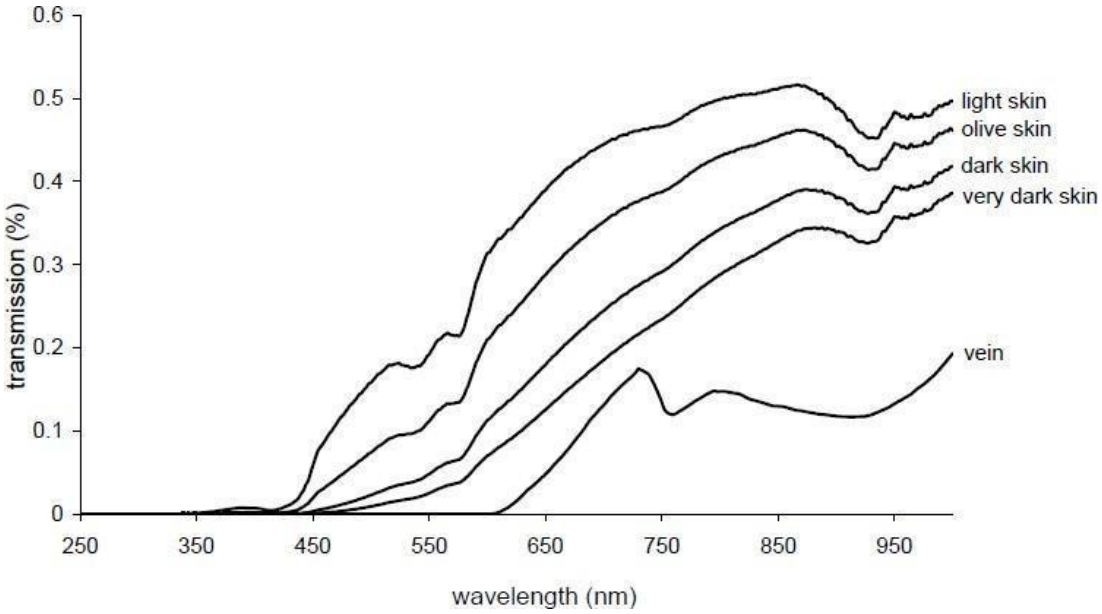

Figure 3.6. Transmission (%) of light through different skin types [22]

3.2.3 Visualization of Blood Vessels with Visible Light and NIR Infrared

The Visible Light window is used for several medical imaging purposes ,such as spectroscopy and tomography .In the70s,visualization of peripheral blood vessels was

explored by several researchers for the first time, using infrared photography or a TV infra scope [23].The used methods did not allow real-time visualization.

More recently, due to technological developments, new techniques have become available to make real-time NIR imaging possible, mostly due to intension arrow band visible NIR light sources (light emitting diodes, LEDs) and cameras with a high sensitivity for NIR light. The new methods of visualization of blood vessels were not immediately used to facilitate

peripheral venous or arterial access, but for biometric identifications by vein patterns, monitoring of physiological parameters such as local blood flow and oxygenation [24, 25]. However, more recently, several researchers have explored the possibility of using visualization of blood vessels to facilitate peripheral venous or arterial access.

At the start of the research described in this thesis, only the VV, at that moment still a bulky device, and the Vascular Viewer were available, but rather expensive. Therefore, in this project the relatively low cost, vascular imaging system based on trans illumination of visible NIR light figure (3.6).

Figure 3.7 Veins in the hand of an adult woman, skin type II, with (left to right) the VeinViewer, the AccuVein and the VascuLuminator[25]

3.2.4 Safety of Visible Light and NIR Light for Skin

Figure(3.7) shows the rise in temperature both by the NIR light itself, using a light guide, and by the NIR LED in direct contact with the skin. As can be seen only a slight rise in temperature of ~ 1◦C is observed when the light guide was used. However, when the NIR LED was placed directly in contact with the skin, the temperature rise is much higher (7◦C), because the LED itself generates much heat[26].

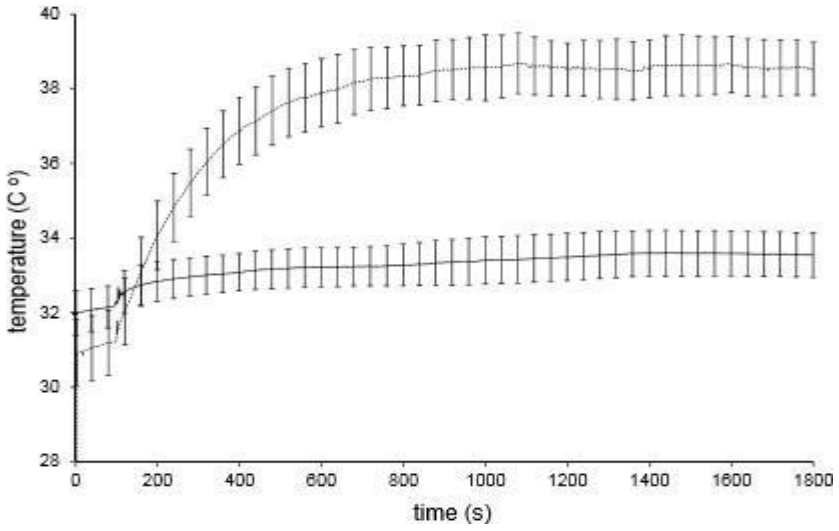

Figure 3.8 Temperature rise of the tissue by NIR light guide and by the visible light in dir contact. [26]

Temperature rise of the tissue by NIR light guide and by the visible light in direct skin contact. Measurement of the light guide is shown by the solid line and of the LED in skin contact by the dotted line. Vertical lines show the SD values. The light source was turned on at 100 s. Environmental temperature was stable at 22.

4.1 Hardware design

4.1.1 NIF and visible LEDs (Digital Control)

According to the preceding study in Chapter 3,the best wavelength to penetrate the forearm skin and reach the vein is623 -700 nm giving comfortable radiation to human body .

(CR5111A-WY,and (ELD-650)and (LED690-03AU) LEDs are chosen ,visible and infrared light emitting diode uses high reliability liquid phase epitaxial grown GaAlAs. Optimized for high power, high efficiency and provides the required wavelength(625-700) nm, the LEDs connect in digital part of Arduino to give him power 5V and controller the LEDs light intensity. A set of three LEDs was designed as shown in Fig (4.1), to sets of the same act is used in final Design

Fig 4.1

4.1.2 Power supply and Datec-Pocket-Box

The voltage requirement of every major component is within the range of (3 volts to 3.6 volts ,therefore for portability, a lithium-ion battery with bms charging module provide the necessary voltage to operate the project as shown in figure 4.2

Figure (4.2): battery 3.7Volts

4.5.1 Control switch

It turn (on/off) the system , is chosen a switch and chosen a rocker switch 65112- BB-1V to control the device.

The 651122-BB-1V is a single-pole single-throw (SPST) sub-miniature Rocker Switch with

0.187-inch tab terminal, vertical molded-in legend and ON-OFF functionshown on Figure(4.3) The 651 series switch fits in a standard rectangular cut-out and is designed to provide ease of insertion along with superior panel retention qualities. A high profile rocker contacts provide the user with a crisp positive-type feel.

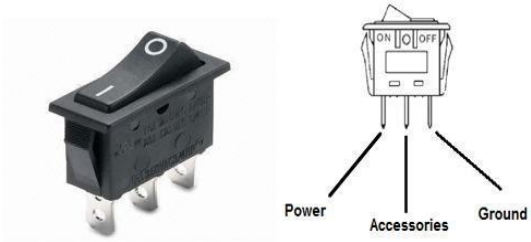

Fig 4.3: Rocker Switch

System Implementation and Testing

In this chapter we discuss the construction and the results of the project are discussed , a prototype system is implemented and tested in this chapter. The full design of device when connected all component, and connect the system with rocker switch to turn on/off the system and collect the component inside the Datec-Pocket- Box is shown in figure 5.1

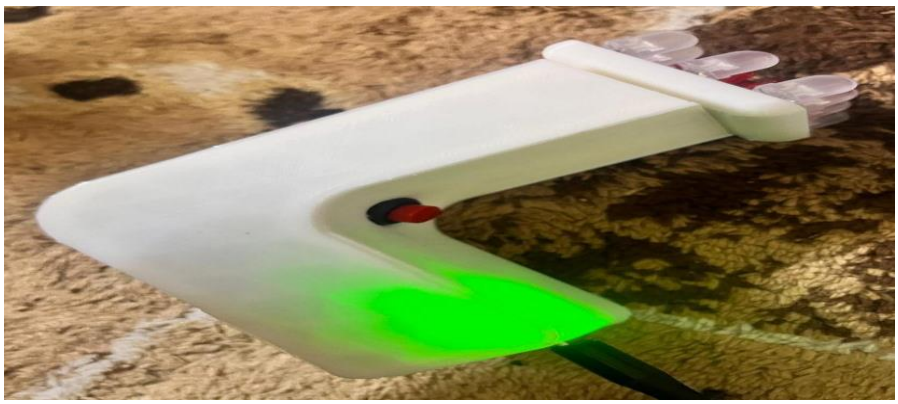

Figure 5.1

The hardware components are then examined by doing the appropriate test for each stage as will be discussed in the following sections.

5.1 LEDs

The board is cut shape of like ―U‖ and the LEDs are connected in the inner edge of it to give suitable area to detect the vein and put it in the PCB board along the inner edge of the center of hole, the anode lead nearest the center and connected him with Vcc from battery ,

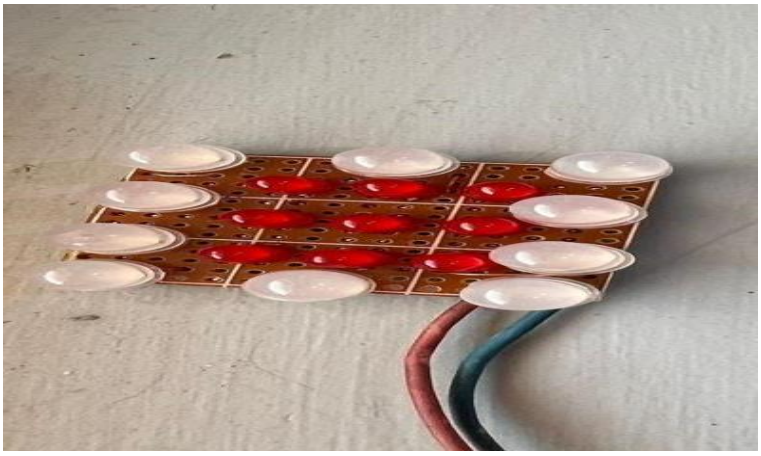

Fig 5.2**: The LEDs on the blanc circuit board**

Results and Conclusions

6.1 Results and analysis

The output from the design can be seen as shown figure (6.1)

Fig 6.1: Test of the final shape of device

The device was tested on a patient arm and gives a positive results and showed the vein as shown in Figure (6.2) the black line in red area is the vein, the figure is small resolution because the LEDs affect the negatively to the camera .

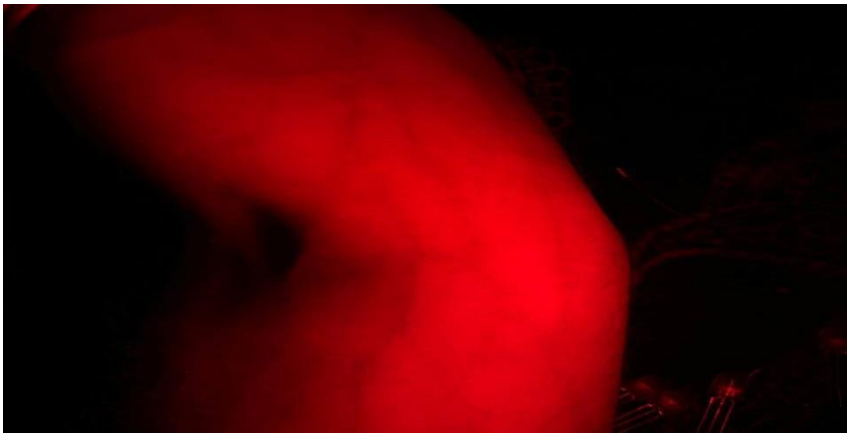

Fig 6.2: result of output device.

6.2 Discussions and conclusions

This technique has been found to be especially useful in different type skin where veins are difficult to identify.

It's feasible to consider routine use of these device to improve the safety dermal of pain and any side effect about injections

In conclusion the imaging in NIR range (650_700)nm provides relative good contrast of subcutaneous veins , and the use of NIR light vein viewer device for vascular access in critically ill children can decrease the total medical time and cost , the device was well received by our patients,, their families and staff.

6.3 Future work

6.3.1 Portable robot venipuncture 6.3.2 Vein finder device for android 6.3.3 IR VV camera with softwar

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