A COMPARATIVE SUDY BETWEEN VISUAL, NEAR INFRARED AND INFRARED IMAGES FOR THE DETECTION OF VEINS FOR INTRAVENOUS CANNULATION

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The process of identification and locating of veins plays an important role to reduce health care cost and suffering of patients during intravenous cannulation. This paper compares between three technologies to assess their suitability and capability for the detection of veins. Three types of cameras are used in this study, a visual camera, an infrared camera and a near infrared camera. The collected data has then been subjected to analysis and comparison using different image processing techniques, namely grayscale, invert grayscale, histogram equalisation, edge detection (difference of Gaussians) and unsharp mask enhancement to improve the visualisation of veins. In this study, the near infrared images supported by suitable LED illumination has been found to be the most effective technology and the most cost effective for the visualisation of veins.

Keywords - Vein locating systems; intravenous access; infrared thermography; vein detection; visualisation enhancement.

Introduction

Peripheral intravenous cannulation is the procedure of inserting a cannula into the peripheral veins, in most cases the veins of the hand or forearm. It is used for many medical procedures such as maintaining hydration, administering blood or blood components and administering drugs such as antibiotics [1]. Numerous studies have identified the difficulties faced by clinical staff to perform intravenous cannulation [2]. For example, in the USA it is estimated that more than 400 million intravenous (I.V.) catheters are used daily to deliver medicine in the USA with success rate of about 72.5% in the first attempt [3].

The use of several attempts for intravenous cannulation increases the suffering of patients, and could cause damage to veins and neighboring tissues. Therefore, it is vital to setup the route of the peripheral vein effectively on the first attempt. Astonishingly, there is presently limited literature regarding the visibility of veins in patients or the patient characteristics associated with difficult IV access. Earlier studies reported a range of aspects that influence vein visibility needed for vein cannulation [4, 5, 6, 7]. Patients who have difficult venous access are a major challenge for modern medical care. A patient's level of hydration influence the ability to identify their veins. If the patient is obese, normal cues are typically absent making venous access enormously complex. Pediatric patients bring their own challenges with smaller vessels.

Problem statement

- The major problem faced by the doctors today is the difficulty in accessing veins for intravenous drug delivery. With improper detection of veins, several problems such as bruises, rashes, blood clot etc. could occur.
- Subcutaneous fat or dark skin color reduces the visualization of blood vessels underneath the skin.
- Gaining intravenous access in children can be difficult.

This paper is aiming to compare between visual, infrared and near infrared images for the detection of veins and to establish an easy, compact, safe and reliable visualization device with minimal interference in the usual routine of vessel puncturing.

Vein Locator Systems

Many vein locator systems are currently available in research and industry to improve vascular access. The current vein locating systems available for this purpose in the market have some limitations, drawbacks and are somehow costly. There are various challenges to be found throughout the design and implementation of a device such as the lighting system, the image processing algorithms, the physical design and the cost. Although, a few devices based on the infrared technique have been implemented, there still exists a strong need to develop such medical devices. Table 1 presents a summary of the most common vein locator systems available in industry.

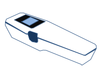
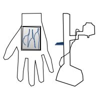
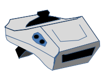
Vein Locator Systems	Company	Working Method	Schematic Presentation
AccuVein AV300 Vein Viewing System	AccuVein®	Near-infrared is used to locate peripheral veins beneath the surface of the skin.	
Vein locator BS2000+	Wuxi Belson Medical System Co.,LTD	Vein locator BS2000+ uses near-infrared light and LED as light source.	
Veinlite®	Warrior Edge, LLC	It works by illuminating the de-oxygenated blood in veins.	
Economical Dualhead Vein locator BM1000	Wuxi Belson Medical System Co.,LTD	It uses near-infrared light source.	
VascuLuminator	DKMP bv	It works with the help of near-infrared light source.	
Luminetx VeinViewer	Luminetx	A near-infrared LED source differentiates red blood cells of subcutaneous veins from surrounding tissues and arteries.	
Veinsite hands-free system	VueTek Scientific	It uses near-infrared light to image superficial veins to a depth of 7mm.	

Table 1. Vein locators with their working methods and schematic diagrams [8, 9, 10, 11, 12, 13, 14]

To visualise the veins accurately there are limitations in relation to capabilities of different vein locating systems presently available in the market. The main focus of this study is on the detection of veins and the enhancement of visualisation using different camera technologies and image processing.

Methodology

Schematic diagram of the methodology is shown in Fig.1. The visual, near infrared and infrared images are captured and processed by different image processing techniques to enhance the visualisation of veins. Regions of interest are selected in all images, processed by image processing techniques presented in Fig.1 and prepared for a comparison process.

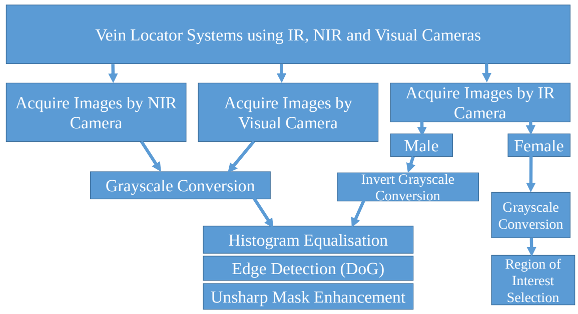


Fig. 1. The research methodology.

Experimental work

A vein locator system is designed to take images of veins in hands/forearms using all infrared, near infrared and visual cameras at a time. The vein locator system is connected to a laptop in which three software are used to capture or analyse data in the form of images which are AMCap for visual camera by Wintec, Quickcam for near infrared camera by Logitec and FLIR report 2.2 for high resolution infrared camera FLIR E25. Vein finding system consists of a camera holder/fixture with rigid support to rest the subject's hand, several types of cameras and an electronic circuit to control the intensity of LED lights for visual and near infrared data.

Results

Tables 2 to 4 present the main results of the study. Images are taken at different distances from cameras and with all possible combinations of intensities of LED lights. All obtained images are of same subject (female) except infrared images which are also captured of a male subject for making a comparison between male and female infrared images before and after cold stimulation.

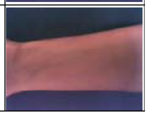
Distance of arm from Wintec visual camera (low resolution)	Intensity of light	Intensity of infrared light	Obtained image
Zoom out	High	Low	
Zoom out	High	High	
Zoom out	Low	Low	
Zoom in	Low	No effects	
Medium	Low	No effects	

Table 2. Visual images data

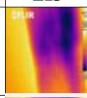
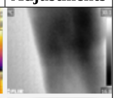
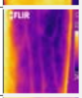
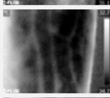
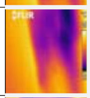
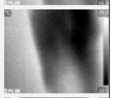
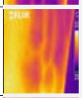
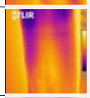
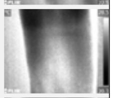
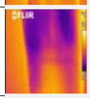
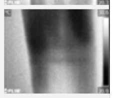
Male			Female		
Time	**IR Images by FLIR E25**	**Grayscale Images after Temperature Adjustments**	**Time**	**IR Images by FLIR E25**	**Grayscale Images after Temperature Adjustments**
Before cold stimulation			Just after cold stimulation (Arm)		
Just after cold stimulation			27 seconds after cold stimulation (Arm)		
32 seconds after cold stimulation			Just after cold stimulation (Wrist)		
Hand image after cold stimulation			15 seconds after cold stimulation (Wrist)		

Table 3. Infrared images before and after cold stimulation

Discussion

Images in Tables 2 to 4 are processed by different image processing techniques and presented in Table 5. Firstly regions of interest are selected for all images. Secondly all NIR and visual images are converted to grayscale. Thirdly color levels are adjusted using histogram equalisation technique when black point is set at a value of 50 whereas white point at 200. Fourthly edge detection (difference of Gaussians) is applied selecting smoothing parameters such as radius 1 = 250 and radius 2 = 8.0. Finally unsharp mask enhancement is done on all NIR and visual images with these parameters such as radius = 380, amount = 4.7 and threshold = 38. IR male images after selecting ROI are converted to invert grayscale. Then same image processing techniques are applied as above with only difference of unsharp mask enhancement parameters which are; radius = 40, amount = 5 and threshold = 40. Female IR images are not affected much by above image processing techniques so they are just converted to grayscale after selecting ROI. NIR, visual and IR images are arranged in Table 5 after image processing for comparison of three technologies to assess their suitability for the detection of veins.

Intensity of light	Intensity of infrared light	Obtained image
Low	Low	
High	Low	
Moderate	Low	
Low	Moderate	
High	Moderate	
Moderate	Moderate	
Low	High	
High	High	
Moderate	High	

Table 4. Near Infrared data

Qualitatively it is resulted that veins in NIR images of Table 4 can be seen clearly when compared to veins in visual and IR images of Tables 2 and 3 respectively. Obviously best results for the detection of veins are obtained by near infrared camera at several combinations of intensities of light and IR light as shown in Table 4 and Table 5.

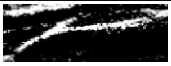
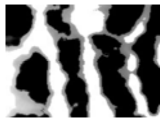
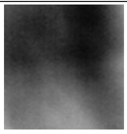
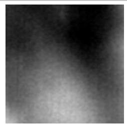
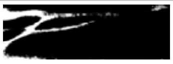
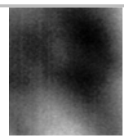
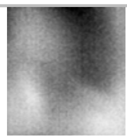
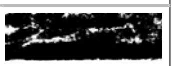
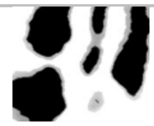
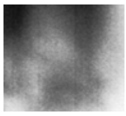
Processed Near Infrared Images			Processed Low and High Resolution Visual Images	Processed Infrared Images	
Intensity Combinations		Processed Near Infrared Images		Male	Female
Light Intensity	IR Intensity				
Low	Low				
High	Low				
Moderate	Low				
Low	Moderate				
High	Moderate				
Moderate	Moderate				
Low	High				
High	High				
Moderate	High				

Table 5. Processed near infrared, visual and infrared images.

Conclusions

This study has compared between visual, infrared and near infrared technologies for the detection of veins. It has been found that using grayscale image processing combined with histogram equalisation, edge detection (difference of Gaussians) and enhancement (unsharp mask) make the near infrared technology with suitable LEDs lighting intensities, the most efficient technology to be used. The results also show that using a cold press (cold stimulation) for IR images helps to enhance the visualisation of veins. Further work will be needed to compare the three technologies for a wide ranges of image processing techniques.

References

1. http://www.ruh.nhs.uk/training/prospectus/clinical_skills/documents/cannulation_and_venepuncture_workbook.doc, accessed on 25 August 2015
2. Doniger, J. Stephanie, et al. "Randomized controlled trial of ultrasound-guided peripheral intravenous catheter placement versus traditional techniques in difficult-access pediatric patients." Pediatric emergency care 25.3: 154-159 (2009).
3. http://www.terumo-europe.com/Relevant%20Product%20Info/Surflash_%20First%20Puncture%20Success%20Study.pdf, accessed on 25 August 2015.
4. Costantino, G. Thomas, et al. "Ultrasonography-guided peripheral intravenous access versus traditional approaches in patients with difficult intravenous access." Annals of emergency medicine 46.5: 456-461. (2005).
5. Dargin, M. James, et al. "Ultrasonography-guided peripheral intravenous catheter survival in ED patients with difficult access." The American journal of emergency medicine 28.1: 1-7 (2010).
6. Aponte, J. John, et al. "Age interactions in the development of naturally acquired immunity to Plasmodium falciparum and its clinical presentation." PLoS med 4: e242 (2007).
7. Mbamalu, David, and A. Banerjee. "Methods of obtaining peripheral venous access in difficult situations." Postgraduate medical journal 75.886: 459-462 (1999).
8. http://www.accuvein.com/products/catalog/av300-vein-viewing-syste, accessed on 6 July 2014.
9. http://www.aliexpress.com, accessed on 7 July 2015.
10. http://www.veinlite.com, accessed on 8 July 2015
11. http://www.portable-ultrasound-scanner.com, accessed on 27 August 2015.
12. http://www.yueshenyl.cn/product/1896497141-221137422/hot_sale_portable_vascu_luminator_device.html, accessed on 8 July 2014.
13. http://www.techeblog.com/index.php/tech-gadget/25000-vein-viewer-by-luminetx, accessed on 5 July 2014.
14. http://www.vision-systems.com, accessed on 5 July 2014.