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INTELLIGENT HAND VEIN IMAGE EXPOSURE SYSTEM TO AID PERIPHERAL INTRAVENOUS ACCESS

by

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LIST OF ABBREVIATIONS

A/D	Analog to Digital
ADALINE	Adaptive Linear Neuron
ADWMF	Adaptive Spatial Distance-Weighted Median Filter
ANN	Artificial Neural Network
BMF	Binary Median Filter
BNC	British Naval Connector
BP	Back-propagation
CCD	Charge-Coupled Device
CHVD	Competitive Valley Checking Detection
CLAHE	Contrast Limited Adaptive Histogram Equalization
CMOS	Complementary Metal-Oxide Semiconductor
CNN	Cellular Neural Network
CRT	Cathode Ray Tubes
DC	Direct Current
DO	Dark Operate
FFNN	Feed-Forward Neural Network
FHH	Fuzzy Histogram Hyperbolization
FIR	Far-Infrared

FL	Fuzzy Logic
FN	False Negative
FP	False Positive
HE	Histogram Equalization
I/O	Input Output
IR	Infrared
IV	Intravenous
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LM	Leverberg-Marquardt
LO	Light Operate
MLFF	Multi-Layer Feed-Forward
MLP	Multilayered Perception Networks
MSE	Mean Square Error
MNR	Massive Noise Removal
NC	Normally Close
NO	Normally Open
NICE	The National Institute of Health and Clinical Excellence
NIR	Near-Infrared
NTSC	National Television Systems Committee

PC	Personal Computer
PCB	Printed Circuit Board
PSNR	Peak Signal to Noise Ratio
PNN	Probabilistic Neural Network
RBF	Radial-Basis Function
ROAD	Rank Ordered Absolute Difference
ROI	Region of Interest
SAWMF	Selective Adaptive Weighted Median Filter
SLFF	Single-Layer Feed-Forward
SMF	Standard Median Filter
SVMF	Standard Vector Median Filter
SVM	Support Vector Machine
TB	Tuberculosis Bacilli
TN	True Negative
TP	True Positive
VCE	Vein Contrast Enhancer

SISTEM PENDEDAHAN IMEJ SALUR DARAH TANGAN PINTAR BAGI MEMBANTU AKSES INTRAVENA

ABSTRAK

Kesukaran untuk mencapai persisian intravena pada sesetengah pesakit adalah suatu masalah klinikal. Kesukaran ini boleh membawa kepada beberapa kesan negatif seperti pengsan, hematoma (darah terkumpul di luar salur darah, di dalam tisu pesakit) dan kesakitan yang disebabkan oleh suntikan yang berulang kali. Rentetan itu, peralatan pengimejan ultrabunyi dan inframerah telah digunakan bagi membantu capaian kepada salur darah. Walaupun peralatan ini telah menunjukkan kebolehannya untuk membantu capaian kepada intravena, sistem inframerah tidak dapat menghasilkan kejelasan imej corak-corak vena yang memuaskan dan penggunaan ultrabunyi memakan masa yang lama. Oleh itu, penyelidikan ini tertumpu kepada pembangunan sistem pendedahan vena tangan dengan peningkatan kejelasan imej corak-corak vena tangan bagi membantu capaian kepada intravena. Ia terdiri daripada tiga sub-sistem utama iaitu sistem perolehan imej urat tangan, komponen pemprosesan imej dan sistem unjuran urat tangan. Sistem perolehan imej terdiri daripada empat puluh lapan biji diod pemancar cahaya inframerah dekat dengan panjang gelombang $0.89\mu m$. Sistem pemprosesan imej dibahagikan kepada enam peringkat. Pada peringkat pertama, hingar asal corak vena tangan ditapis menggunakan rangkaian neural buatan suap hadapan dan penapis median piawai. Pada peringkat kedua, satu teknik baru berdasarkan ciri-ciri lembah dan hujung jari digunakan untuk mendapatkan rantau berkepentingan yang lebih besar. Pada peringkat ketiga, imej rantau berkepentingan dipertingkatkan dengan menggunakan gabungan hiperbola histogram kabur dan histogram penyamaan dan penyesuaian terhad. Kemudian, pada peringkat keempat, corak vena tangan diruas berdasarkan nilai ambang tempatan. Pada peringkat kelima, corak vena ta-

ngan berhingar dipertingkatkan dengan gabungan Pembetul Piksel Rangkaian Neural Buatan, penapis binari median dan penyikiran hingar besar-besaran. Dalam peringkat terakhir, corak vena tangan yang telah dipertingkatkan akan didaftarkan ke dalam imej vena tangan yang asal. Sub-sistem yang terakhir akan mengunjurkan corak urat tangan yang telah didaftarkan ke atas tangan pesakit. Gabungan teknik Pembetul Piksel Rangkaian Neural Buatan, penapis binari median dan penyikiran hingar besar-besaran yang dicadangkan telah meningkatkan kepekaan imej sehingga 10.664% daripada imej binari yang asal. Perbezaan purata sisihan piawai di antara imej-imej yang ditingkatkan dan imej sebenar ialah 0.02016. Nilai perbezaan ini adalah yang terkecil berbanding dengan imej-imej hasil daripada kaedah peningkatan imej yang lain. Secara keseluruhan, sistem yang dibangunkan telah menunjukkan kemampuan meningkatkan kejelasan imej corak vena tangan untuk memudahkan capaian kepada salur darah. Ia juga mempunyai potensi untuk menjimatkan masa dalam mengenalpasti salur darah yang sesuai dan yang paling penting boleh menghilangkan rasa takut pesakit kepada prosidur capaian salur darah.

INTELLIGENT HAND VEIN IMAGE EXPOSURE SYSTEM TO AID PERIPHERAL INTRAVENOUS ACCESS

ABSTRACT

Difficulty in achieving peripheral intravenous (IV) access in some patients is a clinical problem. These difficulties may lead to some negative impacts such as fainting, hematoma and pain associated with multiples punctures. As a result, ultrasound and infrared imaging devices have been used to aid IV access. Although these devices have shown to be able to aid IV access, infrared system has not been able to produce satisfactorily clear vein patterns and using ultrasound device is time consuming. Therefore, this research focuses on developing a hand vein exposure system with enhanced image of hand vein patterns to aid IV access. It consists of three major sub-systems namely, a hand vein image-acquisition system, image processing component and hand vein image-projection system. The image acquisition system consists of forty eight near-infrared light emitting diode with wavelength of 0.89μm. The image processing system involves six stages. In the first stage, a noisy hand vein image is filtered using a feed-forward neural network (FFNN) based on standard median filter. In the second stage, a newly proposed technique based on finger-webs and finger-tips characteristics is applied to obtain a larger region of interest (ROI). In the third stage, the ROI images are enhanced using a combination of fuzzy histogram hyperbolization and contrast limited adaptive histogram equalization. Then, in the fourth stage, vein patterns are segmented using local adaptive threshold. In the fifth stage, a noisy binary vein patterns are enhanced using a combination of FFNN pixel correction, binary median filter and massive noise removal. In the last stage, an enhanced vein patterns are registered into the original hand vein layout. Finally, the last sub-system projects the registered vein patterns onto a patient's hand. A combination of FFNN pixel correction,

binary median filter and massive noise removal as proposed has been able to increase the sensitivity of binary image of vein patterns up to 10.664% from the original binary image. The average difference in standard deviation between the enhanced images and their truth image is 0.02016. This difference is the smallest in comparison to images obtained based on existing image enhancement methods. The developed system has shown to be able to enhance hand vein image patterns for easy IV access. It has the potential to significantly reduce the average IV access time and most importantly, it could shed patients' fear towards IV access.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Peripheral intravenous (IV) is a process of providing an access for the purpose of blood drawing, IV fluid feeding or administration of medicine in a patient's blood vessel (Costantino et al., 2005). It is one of the most commonly used procedures in emergency clinical care as well as for various diseases and patient's treatment. An IV access is done on a patient by inserting a needle or short plastic tube, called a catheter, through the skin into a vein, usually in the hand or arm. It is often performed manually by phlebotomists, physicians, paramedics, anesthesiologist and other nursing staffs.

More than 300 million peripheral IV catheters are placed annually in United States alone (Oniaa et al., 2011). From the large number of practices, it is usually hypothesized that the paramedics are proficient with their insertion procedure. However, that is not always the case. It was reported that world-wide 10% of attempts to establish an IV line has failed (Encyclopedia, 2009). A study conducted in France reported that paramedics had 76% IV success rate during the first attempt and 98% at the second attempt for 669 enrolled patients (Minville et al., 2006). Another study in United States reported that 9% patients from a total of 249 required more than four IV attempts (Lininger, 2003).

IV access can be technically challenging due to factors related to the patients themselves and the skills of the paramedics. Patient-related factors can be associated to extreme age, body size, physical activity level, skin color, patient's medical history and patient's with chronic disease (Lynn, 2005). As an example, an injured or a critically illed elderly patient normally has inaccessible peripheral veins that makes IV access more difficult to achieve.

1.2 Problem Statements

Up to date, traditional methods such as distention (give a pressure to venous), palpation (method of feeling with the fingers or hands during a physical examination) and visualization are still employed by paramedics in the process of obtaining blood vessel. In addition, there is a number of approaches which can be used to enhance the visibility and palpability of peripheral veins, including gentle slapping of the overlying skin, applying proximal tourniquet, fist clenching, application of local warmth and nitroglycerin ointment (Roberge, 2004; Simhi et al., 2008). However, these approaches are still sometimes unable to guarantee the success of establishing peripheral IV line at the first attempt. This is particulary dangerous in an emergency case where fluid must be immediately administrated through IV access.

It is not surprising that despite being taught the correct techniques, paramedics may fail in performing IV access that multiple IV attempts are necessary before a successful access is achieved (McConnell and Mackay, 1996). Such problems are commonly faced by new paramedics who are lack of technical skills and experience in locating veins. The inability to establish an IV line after multiple attempts can also lead to negative emotional and psychological impacts on the paramedics, such as frustration, worry and diminished self-confidence.

Although the percentage of reattempts to gain IV access is small, it can lead to various negative impacts on patients such as fainting or feeling lightheaded, hematoma (blood accumulating under the skin) and pain. In addition, each IV access attempt not only simulates pain, but the frightful and stressful moments faced by children patients particulary, may eventually lead to the development of severe psychological problems such as needle phobia or worse still, hospital phobia (Emanuelson, 2011).

Apart from negative impacts towards patients, multiple attempts also require more time. The average time necessary for a peripheral IV access is reported to be about 2.5 to 13 minutes, sometimes even up to 30 minutes for patients with difficult peripheral veins access (Minville et al., 2006; Lapostolle et al., 2007). This situation can lead to a delay for necessary emergency treatment on an attended patient as well as other waiting patients.

Multiple attempts of peripheral IV access could also increase the cost of equipment. Lynn (2005) reported that an operational cost for inserting a short peripheral catheter is approximately USD32. Hygienically, every new attempt appropriately requires new needle. Hence, if three attempts are established, a short peripheral IV catheter could cost at least USD96 (Lynn, 2005). These costs could indirectly affect the financial viability of the facility.

The current technologies used to aid IV access, such as ultrasound imaging, transillumination and infrared devices are reported to have several disadvantages. Ultrasound approach requires extensive training on hand-eye coordination during the vein cannulation. Besides that, it takes time to locate suitable vein and a needle position accurately. Transillumination devices have been used but they have very limited application and are usually suitable for a baby's small hand. Infrared devices such as AV300 and VeinViewer sometimes produce unclear output image. They are also costly (Lovhoiden, 2004; Soujanya, 2007; Enerspect, 2009). Due to the discussed problems, it is clear that a more reliable device that could aid paramedics in finding veins for peripheral IV access is urgently needed.

1.3 Objectives of the Research

Owing to the problems explained in Section 1.2, this research focuses on the development of a hand vein image enhancement system using intelligent techniques. The objectives of the research are outlined below:

(i) To design and develop a hand vein image acquisition system using IR technology.

(ii) To implement new intelligent techniques for hand vein image enhancement.

(iii) To design and implement a hand vein projection system.

(iv) To access the performance of proposed intelligent hand vein enhancement methods in comparison to several existing enhancement techniques.

This study focusses on developing a system that can solve the problem of unclear visualization of hand vein patterns. In general, this system consists of three main sub-systems. The first sub-system is developed to capture hand vein image using Near-Infrared (NIR) technology. The second sub-system, involves several processes for vein patterns image enhancement using intelligent techniques. Finally, the third sub-system aims at projecting the enhanced hand vein image onto a patient's hand.

1.4 Thesis Outline

This thesis is divided into six main chapters. This chapter presents the overview of peripheral IV access and the problems encountered in the existing techniques. The objectives are also presented. The rest of this thesis is organized as follows.

Chapter 2 briefly reviews four important topics which cover all aspects of this research work. It begins with an overview of peripheral IV access procedures, difficulties at attempting IV access and discusses the current technology utilized to aid paramedics in obtaining IV access. Then, the chapter elaborates on the main device components of a hand vein image acquisition and projection system. Following this is a section on image processing techniques which have been applied on hand vein images. Finally, intelligent techniques focusing on Artificial Neural Network (ANN) and Fuzzy Logic (FL) that have been employed to solve hand vein image-processing-related problems are also presented.

Chapter 3 explains the hardware components for development of a hand vein image acquisition system. This includes justification in determining the best design and features for each components to be used in the hardware system. A prototype of the full system is also presented. Finally, the chapter explains the process of acquiring hand vein images.

Chapter 4 explains the software implementation work involved in developing the proposed intelligent hand vein enhancement technique. In this work, ANN and FL have been applied at different stages. The proposed technique involves six stages of image processing; Feed-Forward Neural Network (FFNN)-based Standard Median Filter (SMF), region of interest (ROI) extraction, grayscale image enhancement, segmentation of vein patterns, binary image enhancement, image registration and projection. The details of each stage is thoroughly explained in separate sections.

Chapter 5 presents the results of the developed hardware and software systems. This includes a discussion on the optimal wavelength as a light source obtained for the image acquisition system. It also presents the results of each proposed techniques employed in all image processing stages as aforementioned.

Chapter 6 provides conclusions for the objectives of this research based on the attained results. This is followed by few suggestions that can be implemented for further improvement.