Non-invasive Ultra-wide Band System for Reliable Blood Glucose Level Detection

Article *in* International Journal of Applied Engineering Research · August 2016

6 authors, including:

Md Shawkat Ali
Universiti Malaysia Perlis

Sabira Khatun
Universiti Malaysia Pahang

Latifah Munirah Kamarudin
Universiti Malaysia Perlis

N. J. Shoumy
Charles Sturt University

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 14 (2016) pp 8373-8376

Non-invasive Ultra-wide Band System for Reliable Blood Glucose Level Detection

Md Shawkat Ali, S. Khatun, L. M. Kamarudin, N. J. Shoumy, V. Vijayasarveswari, Monirul Islam
School of Computer and Communication Engineering,
Universiti Malaysia Perlis, Pauh Putra, 02600 Arau, Perlis, Malaysia.

Abstract
Diabetes is a silent killer and rapidly increasing global epidemic worldwide. Change in life style and healthy diabetes diet are the only remedy as this cannot be cured permanently. Checking blood glucose regularly is crucial to diabetes management. Present way of measuring through glucometer where a blood sample is drawn by pricking fingertip and analysis. This invasive painful process cause discomfort to patient. To overcome this distress a non-invasive patient friendly device is in demand. This article presents an Ultra-wide band (UWB) microwave technology with artificial intelligence (AI) based system to detect blood glucose level non-invasively (i,e.. without taking any blood sample). A pair of micro strip patch bio-antenna and an artificial neural network (ANN) with signal acquisition and processing interface was used to setup this system. Centre frequency of 4.7 GHz was transmitted through one side of left hand and forward scattering waveform were received from other side. Characteristic features were extracted from received waveform which was used for pattern recognition and detection process in ANN. The system demonstrated 82% correctness to detect glucose level in blood plasma. It has displayed a consistent and reliable result. Besides it is easy to use, safe and cost effective to end user.

Keywords: Non-invasive, Blood Glucose, Ultra Wide-band, Artificial Neural Network, Diabetes

INTRODUCTION

Diabetes is a chronic condition that occurs when the body cannot produce enough insulin or cannot use the produced insulin effectively. Diabetes and its complications are the major causes of death in most countries[1]. According to International diabetes federation it cause 5 million death worldwide in 2015 and by 2040 there will be around 642 million diabetes patients worldwide[1]. There is no long-lasting treatment to cure from this disease rather to maintain life style and continue healthy diabetes diet. Frequent monitoring of blood glucose is essential part of diabetes management. Present method of measuring through a glucometer which is invasive way. A blood sample is drawn either from vein or by pricking the fingertip and analysis by device[2]. This process is painful and creates discomfort for the patients specially who need to check it several times in a day. Thus development of a reliable non-invasive continuous glucose monitoring technique was in demand for last four decades. A good number of non-invasive technologies were developed but the devices couldn't survive in the market due to inconsistent result. Vashist[3] and Chi-Fuk So et al[4] comprehensively analyzed most of those technologies along with advantages, disadvantages and future challenges. The efforts continuous and new technologies are attempted with. Some recent non-invasive technologies includes Electrocardiogram signal[5], Nuclear magnetic resonance spectroscopy[6], Thermal spectrum measurement[7], Breath acetone analysis[8], Impedance spectroscopy[9], Saliva analysis[10], Scattering spectroscopy[11], Graphene based nanosensor[12] etc. which could achieve initial success. GlucoTrack DF-F from Integrity application Inc.[13] claims to achieve high accuracy to measure blood glucose concentration non-invasively with combination of three technologies (ultrasonic, electromagnetic and thermal). The system is quite expensive and need periodical calibration.

In the field of exploring potential non-invasive solutions one alternative can be Ultra wide band (UWB) imaging technique which have already been used successfully to determine the existence, size and location of breast tumor[14]. This type of systems rely on changes in dielectric properties (permittivity and conductivity) of target tissues or cells. UWB technology has significant advantage due to its easy penetration and non-ionizing nature[15]. Inspired by this, the performance of UWB system is investigated here to observe the change of blood dielectric properties as a function of both blood glucose concentration and frequency. This paper presents preliminary performance investigation of non-invasive blood glucose concentration using UWB system. The remaining of the paper is organized as follows: Methodology with System development is presented in section II, followed by the results and discussion in section III, and conclusion at the end.

METHODOLOGY

Methods

The received wave forms of an UWB signal through an object get varied due to changes of its dielectric properties (permittivity, conductivity) value. It is observed the value of permittivity and conductivity decrease when the glucose concentration increases and the difference is more apparent in the higher frequency range[16]. Thus the changes of dielectric properties of blood plasma considers as a function of both glucose concentration and frequency[17].

Bi-static radar technique was followed by using a pair of homemade UWB Micro strip patch bio-antenna for this experiment. The system consists of a transmitting antenna (Tx) and receiving antenna (Rx) as shown in Fig 1. Tx antenna transmit UWB pulse train through one side of hand mussel, forward scattered signals were received by Rx antenna from the other side. Signal pulse of resonant frequency 4.7 GHz was used here. The experimental system setup is shown in Fig. 2. The total number of received wave forms were 120 collected from the human subjects for this preliminary experiment. After processed these wave forms were fed into the artificial neural network (ANN) module for feature analysis and detection as shown in Fig. 1.

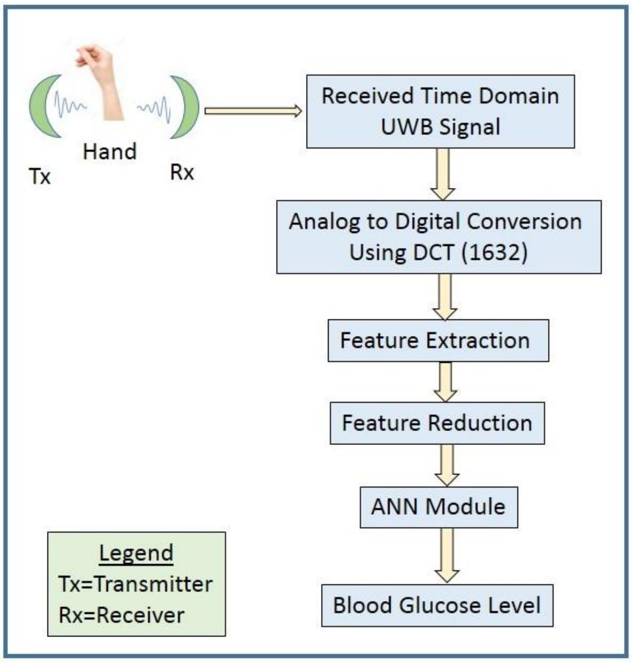

Figure 1: Theoretical system model

System Setup

Pair of UWB micro strip patch antenna (as shown in Fig. 3) was connected to SMA connector through coaxial cable and the other part with an UWB transceiver (P400 RCM)[18]. This self-design antenna has bandwidth, gain and directivity of 8.77 GHz (3.23 GHz to 12 GHz), 6.09 dB and 8.15 dBi respectively. To receive and analysis signal data, a PC was connected to transceiver with Ethernet cable as shown in Fig. 2. A sample received signal is shown in Fig, 4. For collection of actual data from human subject traditional Glucometer was used.

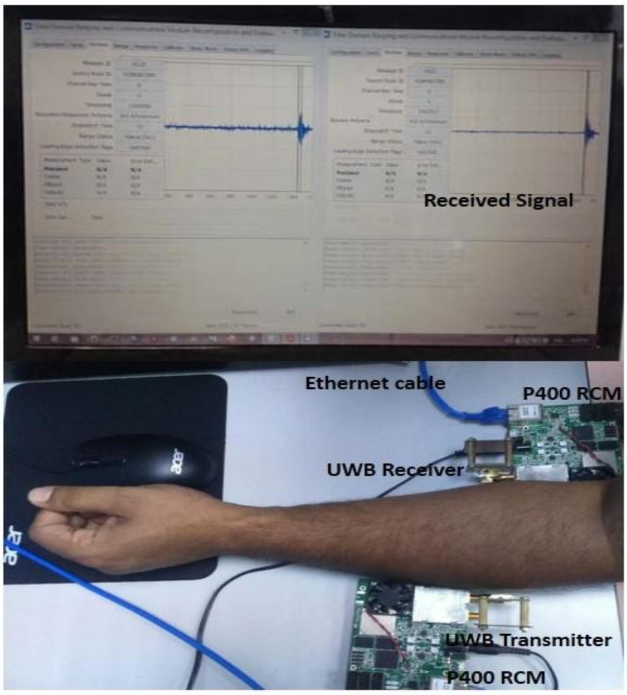

Figure 2: Integrated experimental system setup

Data acquisition

Data samples were collected from students of Universiti Malaysia Perlis and local volunteers with prior approval from authority and written consent of all participants. ACCU-CHEK device[19] was used to measure the actual blood glucose. UWB pulse train of scattered wave forms were received using the developed system through left hand mussel.

Figure 3: Rectangular Patch Antenna

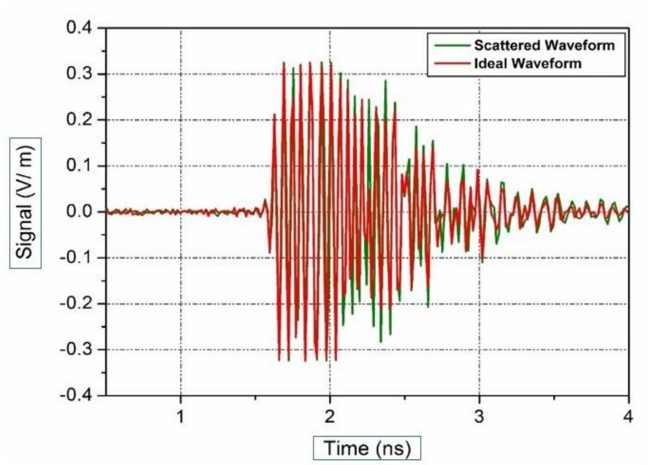

Figure 4: Received UWB pulse

Signal processing

Received UWB scattered waveforms received through hand had different values than the ideal waveform (without through hand) which is easily identifiable. These varied values was considered for feature extraction and pattern recognition purpose[20]. By using discrete cosine transfer (DCT) the received wave forms were converted to 1632 discrete data points which were the extracted features. These large number of features led to delay and computational complexity. Thus, it was reduced to some characteristic features where only four feature values like- standard deviation, mean, maxima and minima were considered. This actually simplify the system by enhancing the processing speed and reduced computational complexity.

Feature classification

Received four point scattered signals were analysed for pattern recognition using MATLAB R2012a software. A feed forward back-propagation artificial neural network (ANN) model was developed with single hidden layer, four input nodes and one output node as shown in Fig. 5. Four input nodes refers to standard deviation, mean, maxima and minima features and one output node refer to blood glucose level. In hidden layer construction number of neurons were tried with 4 to 20 but combination of 8 neurons it provided the optimal construction. Activation function used for hidden and output layer were tan-sigmoid and linear transfer function respectively. Equation 1 was used for ANN regression. Resilient Back-propagation (trainrp), Scaled Conjugate Gradient (trainscg) and Levenberg Marquardt (trainlm) algorithms were used to train the network. Finally, trainlm was used to optimize the whole training process considering the optimal absolute error.

$$y = \sum_{i=1}^{n} w_i x_i + w_0 x_0 \quad (1)$$

Where y, w, and x stands for output value, weight vector and input data set respectively. Following the back-propagation algorithm the value of w was modified and adjusted according to the error at the output level in each training iteration.

The 120 data samples were divided into three groups as follows to measure and analysis the system performance:

- Training: 84 samples (70%)
- Validation: 18 samples (15%)
- Testing: 18 samples (15%)

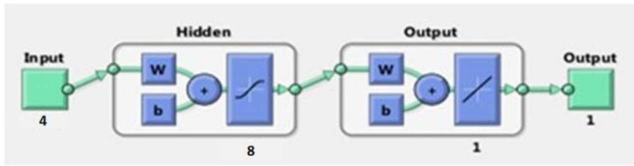

Figure 5: Neural Network Model

RESULTS AND DISCUSSIONS

Measured performance parameter was detection of blood glucose concentration level. Training, testing and validation steps were performed through NN and it was observed at ninth epochs (iteration) it gave the best validated result as shown in Fig. 6. For this iteration, the NN output was 5.54 mmol/l which is 18% less than average actual measurement (average of 120 samples), as shown in Table 1. This was a preliminary effort with a consistent result. Initial success consistent with reliability and compare with the existing technologies this is cost effective and a simple one. Human subjects have different hand mussel composition with flash, skin, blood vessel, fat, bone etc which cause deviation in change of dielectric properties. Received signals usually get affected by these artefacts. Generation of signal through a body part with steady and extreme blood contents might exhibit better performance.

Table 1: Relative Accuracy of the System

Investigation type	Avg. Actual Value	System Output	Error	Relative Accuracy
Blood Glucose	6.76	5.54	18%	82%

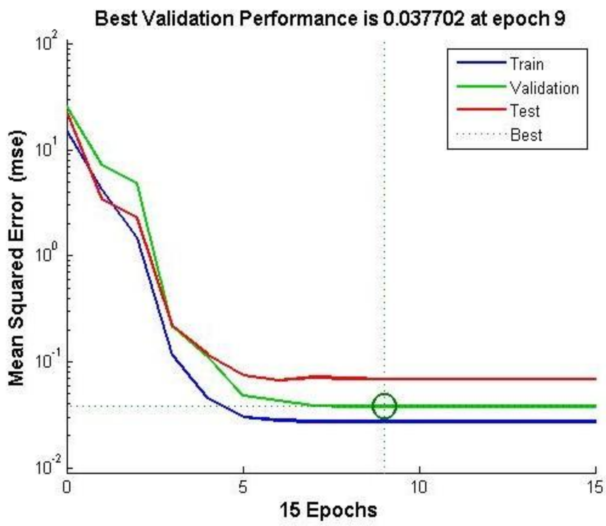

Figure 6: Validation Performance

CONCLUSION

The proof of concept of an UWB based non-invasive blood glucose monitoring system is validated here through performance analysis. This initial system works with 82% accuracy, showing its suitability in practice. The system is non-invasive, user friendly, affordable and is suitable to be used by doctor in hospital and end users at home for regular checking. Increased sample size, reduced signal to noise ratio and a suitable body part while measuring data can led to better accuracy that is under investigation at present.

ACKNOWLEDGMENT

This work is supported by the Research Grant Scheme, FRGS (Grant no.: 9003-00418) of Ministry of Higher Education, Malaysia. Authors would also like to express their gratitude to the R&D Department and School of Computer and Communication Engineering of Universiti Malaysia Perlis, Malaysia for providing financial (Graduate Assistance) support and research facilities respectively.

REFERENCES

[1] International Diabetes Federation, *DIABETES ATLAS*, 2015.

[2] B. Harrison, R. Markes, P. Bradley, and I. A. Ismail, “A comparison of statistical techniques to evaluate the performance of the Glucometer Elite(R) blood glucose meter,” *Clin. Biochem.*, vol. 29, no. 6, p. 521, 1996.

[3] S. K. Vashist, “Non-invasive glucose monitoring technology in diabetes management: A review,” *Anal. Chim. Acta*, vol. 750, pp. 16-27, 2012.

[4] C. F. So, K. S. Choi, T. K. S. Wong, and J. W. Y. Chung, “Recent advances in noninvasive glucose monitoring,” *Med. Devices Evid. Res.*, vol. 5, no. 1, pp. 45-52, 2012.

[5] A. A. Pulavskyi, S. S. Krivenko, and S. A. Krivenko, “Noninvasive evaluation of glucose concentration in the human blood based on electrocardiograms,” *2015 IEEE 35th Int. Conf. Electron. Nanotechnol.*, pp. 275-277, 2015.

[6] A. Y. Luaibi, A. J. Al-Ghusain, A. Rahman, M. H. Al-Sayah, and H. A. Al-Nashash, “Noninvasive blood glucose level measurement using nuclear magnetic resonance,” *2015 IEEE 8th GCC Conf. Exhib.*, pp. 1-4, 2015.

[7] S. S. K. and A. A. Pulavskyi, “The new method for noninvasive measuring of glucose in human whole blood,” vol. 1, no. May, pp. 69-81, 2013.

[8] D. Guo, D. Zhang, L. Zhang, and G. Lu, “Non-invasive blood glucose monitoring for diabetics by means of breath signal analysis,” *Sensors Actuators B Chem.*, vol. 173, pp. 106-113, 2012.

[9] M. A. Arnold, “Non-invasive glucose meter,” no. 7, pp. 46-49, 1996.

[10] S. Malik, S. Gupta, R. Khadgawat, S. Anand, N. Delhi, and N. Delhi, “Monitoring Approach Using Saliva,” no. 2, 2015.

[11] O. S. Abdalsalam and A. A. Awouda, “Non-invasive Glucose Monitoring Using Scattering Spectroscopy,” *Am. J. Biomed. Eng.*, vol. 4, no. 3, pp. 53-59, 2014.

[12] X. Xiong, P. Patra, J. Hu, and P. Wu, “Biochip with Graphene-based Nanosensor for Non-invasive Glucose Sensing Design and Working Principle,” p. 6604, 2016.

[13] E. Naidis, M. Sc, Y. Mayzel, and B. Sc, “Noninvasive Glucose Monitoring: Increasing Accuracy by Combination of Multi-Technology and Multi-Sensors,” vol. 4, no. 3, pp. 583-595, 2010.

[14] S. A. AlShehri, S. Khatun, A. B. Jantan, R. S. A. Raja Abdullah, R. Mahmood, and Z. Awang, “Experimental Breast Tumor Detection Using Nn-Based Uwb Imaging,” *Prog. Electromagn. Res.*, vol. 111, no. December 2010, pp. 447-465, 2011.

[15] C. G. Bilich and I. Chlamtac, “Bio-Medical Sensing using Ultra Wideband Communications and Radar Technology PhD Proposal For the 20 th Cycle of the Program in Information and Communication Technologies Student□: Advisor□: Bio-Medical Sensing using Ultra Wideband Communications and Rada,” *Heart*, no. January 2006, 2006.

[16] E. Topsakal, T. Karacolak, and E. C. Moreland, “Glucose-dependent dielectric properties of blood plasma,” *2011 URSI Gen. Assem. Sci. Symp.*, pp. 1-4, 2011.

[17] T. Karacolak, E. C. Moreland, and E. Topsakal, “Cole-Cole Model for Glucose-Dependent Dielectric Properties of Blood Plasma for Continuous Glucose Monitoring,” *Microw. Opt. Technol. Lett.*, vol. 55, no. 5, pp. 1160-1164, 2013.

[18] Time Domain Corporation, Comings Research Park, 330 Wynn Drive, Suite 300, Hantsville, Al 35805, USA.

[19] B. S. Karon, G. Y. Gandhi, G. A. Nuttall, S. C. Bryant, H. V. Schaff, M. M. McMahon, and P. J. Santrach, “Accuracy of Roche Accu-Chek Inform whole blood capillary, arterial, and venous glucose values in patients receiving intensive intravenous insulin therapy after cardiac surgery,” *Am. J. Clin. Pathol.*, vol. 127, no. 6, pp. 919-926, 2007.

[20] F. Amato, A. López, E. M. Peña-Méndez, P. Vaňhara, A. Hampl, and J. Havel, “Artificial neural networks in medical diagnosis,” *J. Appl. Biomed.*, vol. 11, pp. 47-58, 2013.