Non-Invasive Diabetes Level Monitoring System using Artificial Intelligence and UWB

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Abstract. Diabetes is a silent-killer disease throughout the world. It is not curable, therefore, regular blood glucose concentration levels (BGCL) monitoring is necessary to be healthy in a long run. The traditional way of BGCL measurement is invasive by pricking and collecting blood sample from human arm (or fingertip), then measuring the level either using a glucometer or sending to laboratory. This blood collecting process produces significant discomfort to the patients, especially to the children with type-A diabetes, resulting increased undetected-cases and health-complications. To overcome this drawbacks, a non-invasive ultra-wideband (UWB) BGCL measurement system is proposed here with enhanced software module. The hardware can be controlled through the graphical user interface (GUI) of software and can execute signal processing, feature extraction, and feature classification using artificial intelligence (AI). As AI, cascade forward neural network (CFNN) and naïve bayes (NB) algorithms are investigated, then CFNN with four independent features (skewness, kurtosis, variance, mean-absolute-deviation) are found to be best-suited for BGCL estimation. A transmit (Tx) antenna was placed at one side of left-earlobe to Tx UWB signals, and a receive (Rx) antenna at opposite side to Rx transmitted signals with BGCL marker. These signals are saved and used for AI training, validation and testing. The system with CFNN shows approximately 86.62% accuracy for BGCL measurement, which is 5.62% improved compared to other methods by showing its superiority. This enhanced system is affordable, effective and easy-to-use for all users (home and hospital), to reduce undetected diabetes cases and related mortality rate in near future.

Keywords: UWB, Non-invasive Measurement, Blood Glucose Concentration Level, cascade forward neural network.

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References

1. (NIH), N.I. of D. and D. and K.D.: Your Guide to Diabetes; Type 1 and Type 2. Natl. Inst. Diabetes Dig. Kidney Dis. 14, 1–67 (2013).
2. Mathers, C.D., Loncar, D.: Projections of global mortality and burden of disease from 2002 to 2030. PLoS Med. 3, 2011–2030 (2006). https://doi.org/10.1371/journal.pmed.0030442.
3. Vashist, S.K.: Non-invasive glucose monitoring technology in diabetes management: A review. Anal. Chim. Acta. 750, 16–27 (2012). https://doi.org/10.1016/j.aca.2012.03.043.
4. Freer, B.: Feasibility of a Non-Invasive Wireless Blood Glucose Monitor. Theses. 1–84 (2011). https://doi.org/10.1007/s13398-014-0173-7.2.
5. Li, N., Zang, H., Sun, H., Jiao, X., Wang, K., Liu, T.C.Y., Meng, Y.: A noninvasive accurate measurement of blood glucose levels with Raman spectroscopy of blood in microvessels. Molecules. 24, (2019). https://doi.org/10.3390/molecules24081500.
6. Rondonuwu, F.S., Setiawan, A., Karwur, F.F.: Determination of glucose concentration in aqueous solution using FT NIR spectroscopy. In: Journal of Physics: Conference Series. Institute of Physics Publishing (2019). https://doi.org/10.1088/1742-6596/1307/1/012019.
7. Guo, D., Zhang, D., Li, N.: Monitor blood glucose levels via breath analysis system and sparse representation approach. In: Proceedings of IEEE Sensors. pp. 1238–1241 (2010). https://doi.org/10.1109/ICSENS.2010.5690611.
8. Domschke, A., Kabilan, S., Anand, R., Caines, M., Fetter, D., Griffith, P., James, K., Karangu, N., Smith, D., Vargas, M., Zeng, J., Hussain, A., Yang, X., Blyth, J., Mueller, A., Herbrechtsmeier, P., Lowe, C.R.: Holographic sensors in contact lenses for minimally-invasive glucose measurements. In: Proceedings of IEEE Sensors. pp. 1320–1323 (2004). https://doi.org/10.1109/icsens.2004.1426425.
9. Osiecka, I., Pałko, T.: Overview of some non-invasive spectroscopic methods of glucose level monitoring, https://www.infona.pl/resource/bwmeta1.element.baztech-0da018fd-b2ae-4dd6-b9c3-95e925c4ab3b, (2016).
10. Pickup, J.C., Hussain, F., Evans, N.D., Rolinski, O.J., Birch, D.J.S.: Fluorescence-based glucose sensors, (2005).

https://doi.org/10.1016/j.bios.2004.10.002.
11. Osiecka, I., Pałko, T., Łukasik, W., Pijanowska, D., Dudziński, K.: Impedance spectroscopy as a method for the measurement of calibrated glucose solutions with concentration occurring in human blood. Adv. Intell. Syst. Comput. 519, 211–216 (2017). https://doi.org/10.1007/978-3-319-46490-9_30.
12. Arakawa, M., Sakaki, H., Nagasawa, K., Fukase, A., Mori, S., Yashiro, S., Ishigaki, Y., Kanai, H.: Red Blood Cell Aggregation Measurement with 40-MHz Ultrasound Has a Possibility for Noninvasive Evaluation of Blood Glucose Level in Patients with Diabetes. In: IEEE International Ultrasonics Symposium, IUS. IEEE Computer Society (2018). https://doi.org/10.1109/ULTSYM.2018.8580086.
13. Li, R., Liu, G., Xia, X., Liu, T., Hu, Z.: The studies of noninvasive blood glucose monitoring using optical coherence tomography. In: Ma, X., Wu, F., Fan, B., Li, X., and Zhang, Y. (eds.) 9th International Symposium on Advanced Optical Manufacturing and Testing Technologies: Optical Test, Measurement Technology, and Equipment. p. 44. SPIE (2019). https://doi.org/10.1117/12.2505124.
14. Yeh, S.J., Hanna, C.F., Khalil, O.S.: Monitoring blood glucose changes in cutaneous tissue by temperature-modulated localized reflectance measurements. Clin. Chem. 49, 924–934 (2003). https://doi.org/10.1373/49.6.924.
15. FCC News Release:, https://transition.fcc.gov/Bureaus/Engineering_Technology/News_Releases/2002/nret0203.html, last accessed 2019/12/10.
16. Lim, E.G., Wang, Z., Lei, C.-U., Wang, Y., Man, K.L.: Ultra Wideband Antennas-Past and Present.
17. Topsakal, E., Karacolak, T., Moreland, E.C.: Glucose-dependent dielectric properties of blood plasma. In: 2011 30th URSI General Assembly and Scientific Symposium, URSIGASS 2011 (2011). https://doi.org/10.1109/URSIGASS.2011.6051324.
18. Xiao, X., Li, Q.: A Noninvasive Measurement of Blood Glucose Concentration by UWB Microwave Spectrum. IEEE Antennas Wirel. Propag. Lett. 16, 1040–1043 (2017). https://doi.org/10.1109/LAWP.2016.2618946.
19. Ali, M.S., Shoumy, N.J., Khatun, S., Kamarudin, L.M., Vijayasarveswari, V.: Non-invasive blood glucose measurement performance analysis through UWB imaging. In: 2016 3rd International Conference on Electronic Design, ICED 2016. pp. 513–516. Institute of Electrical and Electronics Engineers Inc. (2017). https://doi.org/10.1109/ICED.2016.7804698.
20. Ali, M.S., Khatun, S., Kamarudin, L.M., Shoumy, N.J., Islam, M.: Non-invasive ultra-wide band system for reliable blood glucose level detection. Int. J. Appl. Eng. Res. 11, 8373–8376 (2016).
21. Reza, K.J., Khatun, S., Jamlos, M.F., Fakir, M.M., Morshed, M.N.: Performance Enhancement of Ultra-Wideband Breast Cancer Imaging System: Proficient Feature Extraction and Biomedical Antenna Approach. J. Med. Imaging Heal. Informatics. 5, 1246–1250 (2015).