

Non-Invasive Blood Glucose Monitoring in Ears

Seminar Paper

by

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Abstract

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Journal articles

Joe Bloggs. Title of paper a. *International Journal*, 6(3–4):371–378, 1998. doi: 10.1017/S1754078714006221.

Joe Bloggs. Title of paper b. *International Journal*, 8(9–27):371–378, 1999. doi: 10.1017/S1754078714006221.

Conference contributions

Joe Bloggs. Title of paper c. In *IEEE International Conference*, pages 1–4, April 2015. doi: 10.1509.

Joe Bloggs. Title of paper d. In *IEEE International Conference*, pages 6–45, April 2016. doi: 10.1509.

Bibliography

- Khalida Azudin, Kok Beng Gan, Rosmina Jaafar, and Mohd Hasni Ja'afar. The Principles of Hearable Photoplethysmography Analysis and Applications in Physiological Monitoring—A Review. *Sensors*, 23(14):6484, January 2023. ISSN 1424-8220. doi: 10.3390/s23146484. URL <https://www.mdpi.com/1424-8220/23/14/6484>. Publisher: Multidisciplinary Digital Publishing Institute.
- K. Budidha and P. A. Kyriacou. The human ear canal: investigation of its suitability for monitoring photoplethysmographs and arterial oxygen saturation. *Physiological Measurement*, 35(2):111–128, February 2014. ISSN 1361-6579. doi: 10.1088/0967-3334/35/2/111.
- Denisse Castaneda, Aibhlin Esparza, Mohammad Ghamari, Cinna Soltanpur, and Homer Nazeran. A review on wearable photoplethysmography sensors and their potential future applications in health care. *International journal of biosensors & bioelectronics*, 4(4): 195–202, 2018. ISSN 2573-2838. doi: 10.15406/ijbsbe.2018.04.00125. URL <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6426305/>.
- Ghena Hammour and Danilo P. Mandic. An In-Ear PPG-Based Blood Glucose Monitor: A Proof-of-Concept Study. *Sensors*, 23(6):3319, January 2023. ISSN 1424-8220. doi: 10.3390/s23063319. URL <https://www.mdpi.com/1424-8220/23/6/3319>. Publisher: Multidisciplinary Digital Publishing Institute.
- Shamima Hossain, Bidya Debnath, Sabyasachi Biswas, Md. Junaed Al-Hossain, Adrita Anika, and Syed Khaled Zaman Navid. Estimation of Blood Glucose from PPG Signal Using Convolutional Neural Network. In *2019 IEEE International Conference on Biomedical Engineering, Computer and Information Technology for Health (BECITHCON)*, pages 53–58, November 2019. doi: 10.1109/BECITHCON48839.2019.9063187. URL <https://ieeexplore.ieee.org/document/9063187>.
- Enric Monte-Moreno. Non-invasive estimate of blood glucose and blood pressure from a photoplethysmograph by means of machine learning techniques. *Artificial Intelligence in Medicine*, 53(2):127–138, October 2011. ISSN 1873-2860. doi: 10.1016/j.artmed.2011.05.001.

Boudewijn Venema, Hartmut Gehring, Ina Michelsen, Nikolai Blanik, Vladimir Blazek, and Steffen Leonhardt. Robustness, Specificity, and Reliability of an In-Ear Pulse Oximetric Sensor in Surgical Patients. *IEEE Journal of Biomedical and Health Informatics*, 18(4): 1178–1185, July 2014. ISSN 2168-2208. doi: 10.1109/JBHI.2013.2292118. URL <https://ieeexplore.ieee.org/abstract/document/6671925>.

Mahdi Zeynali, Khalil Alipour, Bahram Tarvirdizadeh, and Mohammad Ghamari. Non-invasive blood glucose monitoring using PPG signals with various deep learning models and implementation using TinyML. *Scientific Reports*, 15(1):581, January 2025. ISSN 2045-2322. doi: 10.1038/s41598-024-84265-8. URL <https://www.nature.com/articles/s41598-024-84265-8>. Publisher: Nature Publishing Group.