Scopus

## Documents

Nawawi, M.M.M., Sidek, K.A., Azman, A.W.

**ECG biometric in real-life settings: analysing different physiological conditions with wearable smart textiles shirts**
(2023) *Bulletin of Electrical Engineering and Informatics*, 12 (5), pp. 2930-2938. Cited 1 time.

**DOI:** 10.11591/eei.v12i5.5133

Department of Electrical and Computer Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia

**Abstract**
The adoption of biomedical signals such as the electrocardiogram (ECG) for biometric is rising in tandem with the increased attention to wearable devices. However, despite its potential benefits, ECG is rarely implemented as a biometric mechanism in real-life wearable applications. Therefore, this research aims to analyse the ECG signals extracted from wearable Hexoskin Proshirt for biometric authentication in different physiological conditions. A total of 11 subjects participated in this study, where the ECG signals were recorded while standing, sitting, walking, and uncontrolled activity. The raw ECG signal is first pre-processed using noise-removal butterworth filters in the time domain, followed by an efficient QRS segmented feature extraction approach. Finally, around 854 datasets were generated for training and validation, while the remaining 300 were used to test the proposed recognition method with a quadratic support vector machine (QSVM). The results show that the proposed method achieved a reliable accuracy above 98% with false acceptance rate (FAR) of 0.93%, false rejection rate (FRR) of 3.64%, and true positive rate (TPR) above 96% on the in-house datasets. This researchs findings confirm the possibility of using ECG biometrics for authentication purposes in various real-life settings with varying physiological parameters using a smart textile shirt. 

**Author Keywords**
Authentication; Biometric; Electrocardiogram; Smart shirt; Smart textile; Wearable

**References**

- Lee, E., Ho, A., Wang, Y.-T., Huang, C.-H., Lee, C.-Y.
**Cross-domain adaptation for biometric identification using photoplethysmogram**
(2020) *ICASSP 2020 - 2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 1289-1293.
IEEE

- Tsukada, Y. T.
**Validation of wearable textile electrodes for ECG monitoring**
(2019) *Heart Vessels*, 34 (7), pp. 1203-1211.

- Khundaqji, H., Hing, W., Furness, J., Climstein, M.
**Smart shirts for monitoring physiological parameters: scoping review**
(2020) *JMIR MHealth UHealth*, 8 (5), pp. 1-19.

- Bin Hwang, H., Kwon, H., Chung, B., Lee, J., Kim, I. Y.
**ECG authentication based on non-linear normalization under various physiological conditions**
(2021) *Sensors*, 21 (21), pp. 1-19.

- Sodhro, A. H., Sangaiah, A. K., Sodhro, G. H., Lohano, S., Pirbhulal, S.
**An energy-efficient algorithm for wearable electrocardiogram signal processing in ubiquitous healthcare applications**
(2018) *Sensors*, 18 (3), pp. 1-21.

- **New heart features for more effective human identification**
(2022) *Int. J. Online Biomed. Eng*, 18 (8), pp. 127-141.
S. S. I

- Barros, A.
  **Data improvement model based on ECG biometric for user authentication and identification**
  (2020) *Sensors*, 20 (10), pp. 1-18.

- Valderrama, W., Magadan, A., Vergara, O. O., Ruiz, J., Pinto, R., Reyes, G.
  **Detection of facial spoofing attacks in uncontrolled environments using ELBP and color models**
  (2022) *IEEE Lat. Am. Trans*, 20 (6), pp. 875-883.

- Boulkenafet, Z., Komulainen, J., Hadid, A.
  **Face spoofing detection using colour texture analysis**
  (2016) *IEEE Trans. Inf. Forensics Secur*, 11 (8), pp. 1818-1830.

- Khalifa, O. O., Jawed, B., Bhuiyn, S. S. N.
  **Principal component analysis for human gait recognition system**
  (2019) *Bull. Electr. Eng. Inform*, 8 (2), pp. 569-576.

- Okokpujie, K., John, S., Ndujiuba, C., Badejo, J. A., Noma-Osaghae, E.
  **An improved age invariant face recognition using data augmentation**
  (2021) *Bull. Electr. Eng. Inform*, 10 (1), pp. 179-191.

- Hamd, M. H., Rasool, R. A.
  **Optimized multimodal biometric system based fusion technique for human identification**
  (2020) *Bull. Electr. Eng. Inform*, 9 (6), pp. 2411-2418.

- Chugh, T., Cao, K., Jain, A. K.
  **Fingerprint spoof buster: use of minutiae-centered patches**
  (2018) *IEEE Trans. Inf. Forensics Secur*, 13 (9), pp. 2190-2202.

- Assiroj, P., Warnars, H. L. H. S., Abdurachman, E., Kistijantoro, A. I., Doucet, A.
  **The influence of data size on a high-performance computing memetic algorithm in fingerprint dataset**
  (2021) *Bull. Electr. Eng. Inform*, 10 (4), pp. 2110-2118.

- Khade, S., Gite, S., Thepade, S. D., Pradhan, B., Alamri, A.
  **Detection of iris presentation attacks using hybridization of discrete cosine transform and haar transform with machine learning classifiers and ensembles**
  (2021) *IEEE Access*, 9, pp. 169231-169249.

- Fang, Z., Czajka, A., Bowyer, K. W.
  **Robust iris presentation attack detection fusing 2D and 3D information**
  (2021) *IEEE Trans. Inf. Forensics Secur*, 16, pp. 510-520.

- Chandrashekhar, V., Singh, P., Paralkar, M., Tonguz, O. K.
  **Pulse ID: the case for robustness of ECG as a biometric identifier**
  (2020) *2020 IEEE 30th International Workshop on Machine Learning for Signal Processing (MLSP)*, pp. 1-6.
  IEEE

- Meng, L., Ge, K., Song, Y., Yang, D., Lin, Z.
  **Long-term wearable electrocardiogram signal monitoring and analysis based on convolutional neural network**
  (2021) *IEEE Trans. Instrum. Meas*, 70, pp. 1-11.

- Lehmann, F., Buschek, D.
  **Heartbeats in the wild: a field study exploring ECG biometrics in everyday life**
  (2020) *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pp. 1-14.
  ACM

- Ye, C., Kumar, B. V. K. V., Coimbra, M. T.
**Human identification based on ECG signals from wearable health monitoring devices**
(2011) *Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies*, pp. 1-5.
ACM

- Pourbabaee, B., Patterson, M., Reiher, E., Benard, F.
**Deep convolutional neural network for ECG-based human identification**
(2018) *CMBES Proc*, 41, pp. 7-10.

- Ashwini, S. R., Nagaraj, H. C.
**Classification of EEG signal using EACA based approach at SSVEP-BCI**
(2021) *IAES Int. J. Artif. Intell*, 10 (3), pp. 717-726.

- Toulni, Y., Drissi, T. B., Nsiri, B.
**Electrocardiogram signals classification using discrete wavelet transform and support vector machine classifier**
(2021) *IAES Int. J. Artif. Intell*, 10 (4), pp. 960-970.

- Ohmaid, H., Eddarouich, S., Bourouhou, A., Timouyas, M.
**Iris segmentation using a new unsupervised neural approach**
(2020) *IAES Int. J. Artif. Intell*, 9 (1), pp. 58-64.

- Althabhawee, A. F. Y., Alwawi, B. K. O. C.
**Fingerprint recognition based on collected images using deep learning technology**
(2022) *IAES Int. J. Artif. Intell*, 11 (1), pp. 81-88.

- Ribeiro Pinto, J., Cardoso, J. S., Lourenco, A.
**Evolution, current challenges, and future possibilities in ECG biometrics**
(2018) *IEEE Access*, 6, pp. 34746-34776.

- Ingale, M., Cordeiro, R., Thentu, S., Park, Y., Karimian, N.
**ECG biometric authentication: a comparative analysis**
(2020) *IEEE Access*, 8, pp. 117853-117866.

- Rathore, A. S., Li, Z., Zhu, W., Jin, Z., Xu, W.
**A survey on heart biometrics**
(2021) *ACM Comput. Surv*, 53 (6), pp. 1-38.

- Uwaechia, A. N., Ramli, D. A.
**A comprehensive survey on ECG signals as new biometric modality for human authentication: recent advances and future challenges**
(2021) *IEEE Access*, 9, pp. 97760-97802.

- Ugi, L. V., Suratman, F. Y., Sunarya, U.
**Electrocardiogram feature selection and performance improvement of sleep stages classification using grid search**
(2022) *Bull. Electr. Eng. Inform*, 11 (4), pp. 2033-2043.

- Jain, A. K., Nandakumar, K., Ross, A.
**50 years of biometric research: accomplishments, challenges, and opportunities**
(2016) *Pattern Recognit. Lett*, 79, pp. 80-105.

- Dong, X., Si, W., Yu, W.
**Identity recognition based on the QRS complex dynamics of electrocardiogram**
(2020) *IEEE Access*, 8, pp. 134373-134385.

- Pinto, J. R., Cardoso, J. S.
**Explaining ECG biometrics: is it all in the QRS?**
(2020) *BIOSIG 2020 - Proceedings of the 19th International Conference of the Biometrics*

*Special Interest Group*, pp. 1-12.
IEEE

**Correspondence Address**
Sidek K.A.; Department of Electrical and Computer Engineering, Malaysia; email: azami@iium.edu.my

**Publisher:** Institute of Advanced Engineering and Science

**ISSN:** 20893191
**Language of Original Document:** English
**Abbreviated Source Title:** Bull. Electr. Eng. Inform.
2-s2.0-85175112253
**Document Type:** Article
**Publication Stage:** Final
**Source:** Scopus