Comparison of a Pragmatic and Regression Approach for Wearable EEG Signal Quality Assessment

Jolanda Witteveen, Paruthi Pradhapan, and Vojkan Mihajlović, *Member, IEEE*

***Abstract*—Wearable electroencephalogram (EEG) solutions allow portability and real-time measurements in uncontrolled conditions. For reliable and reproducible interpretation of the EEG data, it is essential to accurately identify EEG segments contaminated by artefacts. Two data quality indicator approaches are proposed: pragmatic and regression based. The former extracts statistical features and applies data-driven thresholding, while the latter uses a regression model on the same set of statistical features to predict data quality. The performance of the approaches is validated against EEG data recorded during uncontrolled laboratory and free-living conditions, and compared to a validated approach. The proposed approaches achieve average accuracy of over 83% in detecting artefactual data, which is higher than the FORCe signal quality estimation method (≈79%). The main strength of the proposed algorithms is in the significant increase of specificity over the state-of-the-art. The two models perform equally across different databases. Training of the two approaches on free-living conditions data showed better generalization when tested on different types of databases, i.e., uncontrolled laboratory and free-living. Although the accuracy in determining artefact-contaminated data is highest when using a window size of 8 s, the accuracy drop is minor when using shorter window size, demonstrating another advantage over existing methods. Given low complexity of both pragmatic and regression approach, it facilitates a real-time implementation, which is demonstrated using a wearable EEG headset system available at IMEC.**

***Index Terms*—Electroencephalography, signal quality, free-living, data quality indicator, regression, real-time.**

I. Introduction

THE advent of technology and miniaturization has led to increase in health monitoring devices gradually moving from traditional clinical applications (i.e. controlled environments) towards lifestyle and wearable solutions (i.e. uncontrolled environments). From interval checks at a laboratory or hospital, technology has brought us a long way forward in self-monitoring and evaluating activity and fitness, chronic illness and adherence to medication among others, on a regular basis. Recently, wearable brain monitoring platforms focusing on electroencephalogram (EEG) measurements have garnered interest. Particularly, the availability of wearable solutions has allowed exploration of novel applications [1]–[3]. An overview of the different wearable EEG headsets, their specifications and application domain are presented by Balonou and colleagues [4]. These wearable solutions have advantages over traditional brain monitoring systems as they allow portability and real-time measurements in uncontrolled conditions. However, as pointed out by Mihajlović *et al.* [5], various challenges still need to be addressed before such technology can be extensively used in various applications.

Magnitude of electrical activity on the surface of the scalp is typically in the microvolt range and it is susceptible to artefacts emanating from physiological or external sources. Such artefacts, especially ones generated in uncontrolled settings, may render highly contaminated signals making it difficult, if not impossible, to reconstruct artefact-free EEG. For accurate actuation or output interpretation based on the sensing, it is essential to distinguish artefacts from good quality data so that the output is reliable and reproducible. For this purpose, several approaches have been proposed in literature. One approach looks at the properties of the EEG signal containing no or only specific artefacts [6]. Electrode tissue impedance (ETI) is the gold standard for evaluating the electrical contact and stability between the skin and the electrode. ETI is used in many systems to assess whether the electrodes are properly attached to skin after the initial EEG headset mounting (e.g., Advanced Brain Monitoring solutions [7], Emotiv [8]), but also to quantify signal quality [9], [10]. The hypothesis here is that artefacts arising in the EEG are due to interferences in the electrode-skin contact. However, the relationship between contact quality and signal quality is not straightforward, especially in the case of noise stemming from physiological or other electrical sources. Tautan *et al.* [10] reported no relation between signal quality and contact impedance. This intrinsic difficulty in signal quality estimation resulted in many approaches stepping directly into artefact reduction [11]–[13] and avoiding signal quality estimation steps.

Automated artefact reduction is mainly focussed on source-specific artefacts [14]–[16], while only a few studies take a more generic approach, typically using blind source separation

Manuscript received December 6, 2018; revised April 3, 2019 and May 16, 2019; accepted May 26, 2019. Date of publication June 5, 2019; date of current version March 6, 2020. *(Corresponding author: Jolanda Witteveen.)*

The authors are with the Imec The Netherlands, 5656 AE Eindhoven, Netherlands (e-mail: jolanda.bax-witteveen@imec-nl.nl; paruthi.pradhapan@imec-nl.nl; vojkan.mihajlovic@imec-nl.nl).

Digital Object Identifier 10.1109/JBHI.2019.2920381

2168-2194 © 2019 IEEE. Personal use is permitted, but republication/redistribution requires IEEE permission.
See https://www.ieee.org/publications/rights/index.html for more information.

Authorized licensed use limited to: California Polytechnic State University San Luis Obispo. Downloaded on October 06,2026 at 04:52:33 UTC from IEEE Xplore. Restrictions apply.