Brain Data Bank Challenge Events at the Sensors Conference – 2019

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Introduction and Summary

While electroencephalography (EEG) data have been compiled since the 1990s in significant volumes, the quality and usability of available data are uncertain. The term "Brain Data Bank" has been forged since 2015 for sharing in uniformity and simplicity, resembling a bank in providing a common currency with built-in security and privacy. The currency in the BDB sense contains the emotion and intelligence profiled by the brain signals.

The IEEE Brain Data Bank Challenge aims to advance the exciting field of brain signal analysis with multi-disciplinary research and development, by supporting investigation of, preferably, non-invasive sensor activated brain signal measurements in conjunction with other physiological inputs, to explore brain signal multi-modal system methodology and experimental Big Data analytics, Artificial Intelligence (AI) or deep learning for user-centric brain signal and image data bank.

These BDB events have attracted graduate/post-doctorial researchers with faculty guidance, some with entrepreneurial attempts, embracing a multi-disciplinary approach involving brain science, sensors, physiology, psychology, computer science, electric engineering, mechanical engineering, chemistry, medicine, etc. The 2019 Brain Data Bank (BDB) Challenge marked the event's 7th occurrence, and the 2nd time co-located at the Sensors Conference, in Montreal, thanks to the Sensors Council's strategic directions to expand fields of interest into system-oriented, new applications. It started with an inspirational Keynote by Yannick Roy who gauged various deep learning techniques in EEG data analytics (dating back to a decade ago) for an incremental accuracy improvement around 7%. Later team presentations also shed light on the contribution of such AI techniques.

Epilepsy is one of the most prevalent neurological conditions affecting about 1% of the world's population. It is characterized by recurrent and spontaneous seizures which occur due to sudden and excessive synchronizations of neuronal brain activity. Anticonvulsant ("anti-seizure") medication still leaves over a third of patients of all ages suffering from uncontrolled epileptic seizures. Team EpiHack presented a novel approach for the classification of epileptic brain states by combining a Support Vector Machine (SVM) and higher order spectra. Team Kiel demonstrated methodology to detect epilepsy overcoming the constraints of a mobile phone platform. Both employed AI techniques for brain data analysis.

The 1st Place: AI and Advanced Signal Processing: Accurate Classification of Epileptic Brain States

This research project was presented by Team EpiHack, with members: Laura Gagliano & Elie Bou Assi (in figure 1,) affiliated with the Polystim Neurotech Lab, Institute of Biomedical Engineering, Polytechnique Montreal, and the University of Montreal Hospital Center (CHUM), University of Montreal, Canada.

Figure 1. The 1st place, Team EpiHack receiving the award.
(l-r): Fabrice Lebeau (SC General Chair), Elie Bou Assi, Laura Gagliano & Nan Chu (BDB Chair)
Not Shown, Ferdinand Ephrem (BDB-Montreal Co-Chair.)

Highlight of Team EpiHack presentation is shown in Figure 2. More details can be obtained by contacting Laura Gagliano laura.gagliano11@gmail.com.

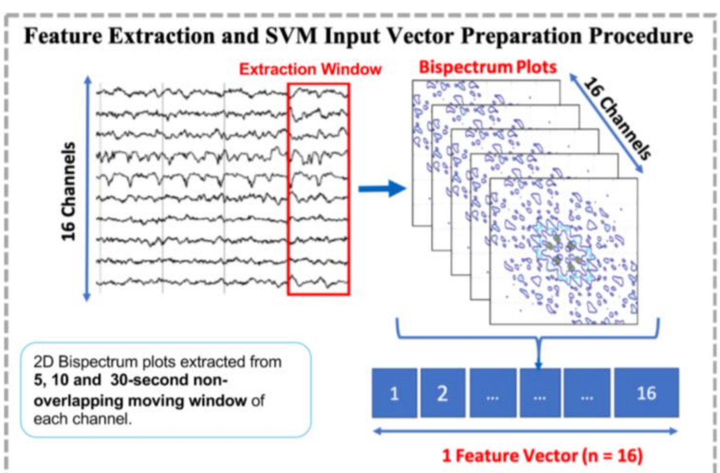

Figure 2. Feature Extraction Procedure Using Bispectrum Analysis.

The EpiHack team explores AI and signal processing techniques to develop novel treatment strategies to control refractory epilepsy including seizure forecasting and brain states classification based on intracranial electroencephalogram (iEEG) signals. While recent studies have presented promising seizure prediction capabilities using classification algorithms based on iEEG recordings, the spectral band power remains the most commonly used feature. However, a proper understanding of seizure mechanisms would allow the development of interpretable algorithms. Team EpiHack evaluated the appropriateness and feasibility of using bispectrum analysis, an advanced higher-order spectra signal processing technique, to accurately characterize different epileptic brain states in humans. To do so, Team EpiHack used the publicly available Melbourne Seizure Prediction Challenge Database which consists of iEEG recordings of seizures (1181 seizures) from 12 patients who participated in the first and only long-term in-man trail using the NeuroVista Ambulatory monitoring device [1]. The analyses showed that bispectrum-extracted features can statistically characterize and classify different epileptic brain states in humans (ictal, preictal, postictal) and indicated that longer extraction windows (30 sec. vs. 5 or 10) yield superior classification accuracies but compromise the computation speed.

The 2nd Place: Epileptic Seizure Detection with Neural Networks for Medical Implants

This research project was presented by Andreas Bahr on behalf of the Team from University of Kiel, with members: Matthias Schneider, Avitha Maria Francis, Hendrik Lehmann, Igor Barg and Andreas Bahr.

Figure 3. The 2nd place, Team University of Kiel receiving the award.
(l-r): Fabrice Lebeau (SC General Chair), Andreas Bahr & Nan Chu (BDB Chair);
Not Shown, Ferdinand Ephrem (BDB-Montreal Co-Chair.)

Team Kiel sought implementation of epileptic seizure detection in ultra-low power implant, an Internet of Things (IoT) application.

The aim of the Team Kiel research project is to develop a medical implant that initiates an emergency procedure in case an epileptic seizure is detected. The medical implant records the brain signals and analyzes the signal with a Convolutional Neural Network (CNN). The CNN has to be implemented on a low-power microcontroller that fits into a medical implant. The goal and challenge is to optimize the network for low-power applications with sensitivity close to 98%.

Figure 4 summarizes the architecture, classification model and detection sensitivity for implementation. More details can be obtained from Andreas Bahr ab@tf.uni-kiel.de.

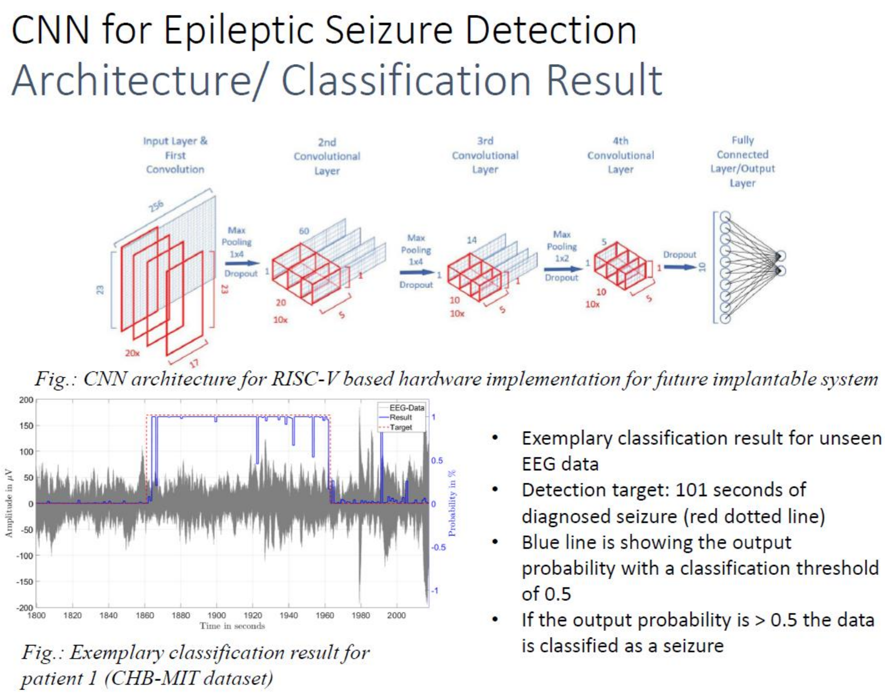

Figure 4. Architecture and Classification to Detect Epileptic Seizure.

A neural network was trained based on real physiological data from 21 patients. The training of the network was done with Matlab Deep Learning toolbox, based on an open source data base (CHB-MIT Dataset). The neural network will be ported on a RISC-V microprocessor. The detection sensitivity is conservatively assessed ~85%, with power consumption ≈ 0.14mW, while classifying 1 sec EEG data. This analysis of the brain signals in an implant will enable a real-time interaction with the patient, reducing the requirements for wireless data transfer and off-line processing drastically.

Team Kiel was also supported by the German Research Training Group 2154 on "Materials for Brain," which investigates nano- and microscale therapeutically active coatings for their suitability as implants to treat three selected diseases of the brain (epilepsy, aneurysm, glioblastoma). Investigations according to material-controlled drug release, implant interactions as well as suitability of the implants for diagnostics with Magnetic Resonance Imaging (MRI) are all accounted for to open up new prospects for novel therapies. The investigation and development of such cutting-edge localized therapies and suitable functional materials requires substantial interdisciplinary collaboration between materials science and medicine.

Participation Experience

Both teams expressed their gratitude to the IEEE Brain Data Bank Challenge Organizers for creating this impactful competition and for allowing them to showcase their work while participating in the Sensors Conference.

Prizes were awarded for their novel approach and their justification of publicly available brain data: Melbourne Seizure Database and CHB/MIT dataset. Participating in this BDB Challenge presents enriching experience and opportunity to share work within the IEEE Brain Initiative community. The Challenge organizing committee, judges and, audience at large, provided very rich discussions. Exchanging ideas during the Challenge and discuss recent progress in research of artificial intelligence for brain signal analysis with leading experts in the field was a great and inspiring experience. These interactions have motivated both teams to explore new avenues of iEEG processing beyond AI while continuing their epilepsy research.

After Montreal, the BDB Challenge concluded the year 2019 by co-locating with yet another IEEE Conference on Big Data, in Los Angeles on December 10. BDB Challenge events, sponsored by the IEEE Brain Initiative*, other than in Montreal, are described in a companion report to be released by the Brain Initiative Newsletter**.

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[1] Cook, Mark J., et al. "Prediction of seizure likelihood with a long-term, implanted seizure advisory system in patients with drug-resistant epilepsy: a first-in-man study." The Lancet Neurology 12.6 (2013): 563-571.

* The mission of IEEE Brain is to facilitate cross-disciplinary collaboration and coordination to advance research, standardization, and development of technologies in neuroscience to help improve the human life. IEEE Brain is a member of the BRAIN Initiative Alliance (BIA) and is actively engaged with many IEEE Societies/Councils, industry, and other organizations bearing similar goals.
** N. Chu, "BDB Challenge Events Encourage Explorations of Neuroscience for Consumer Neurotechnology."