PIEEG: Performance Evaluation of a Motor Imagery Based BCI On a Low-cost, Raspberry Pi 4

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Introduction: Brain-computer interfaces (BCIs) offer a new way to interact with the world for children living with complex needs, but currently require expensive hardware and burdensome software to be used outside of the laboratory [1]. Due to the ongoing global chip shortage and the attempt to find suitable software for signal processing, researchers are seeking to find alternative low-cost BCI devices. Recent research has enabled a low-cost Raspberry Pi 4 (RPi4) to be BCI compatible for measuring and processing of EEG signals [2]. Understanding the behavior of RPi4 while it operates standard BCI procedures such as training classifier models is key to advancing practical applications. This work aims to do so while evaluating performance against traditional desktop and laptop computers to evaluate its potential for implementation beyond the lab setting.

Material, Methods and Results: We employed the BCI competition IV Dataset 2a [3] to evaluate four motor imagery tasks across 22 EEG channels performed by adult participants (n=9). Raw data were band-pass filtered between 7-35 Hz, lower and upper transition bandwidth were selected to be 2.0 Hz and 8.8 Hz respectively. Epochs of 3s were extracted from the dataset into 288 events of four classes (left-hand, right-hand, foot and tongue). Filter length of 413 samples (1.652 sec) was selected and 288 events loaded.

Feature extraction using wavelets and common spatial patterns was applied. Twelve machine learning models were then trained on RPi4, desktop (AMD Ryzen 7 5800X 8-core, 16GB), and laptop (Intel Core i7, 16GB, for Win OS & Mac OS) platforms. The trained models were: Linear discriminant analysis (LDA), K-nearest neighbors (KNN), Support vector machine (SVM), Random forest (RF), Logistic regression (LR), Naïve bayes (NB), Decision tree (DT), Ensemble bagging (EB), Ensemble boosting (EB), Ensemble stacking (ES), Riemannian geometry (RG) and Artificial neural network (ANN). The performance evaluation using the accuracy metric is shown in Fig.1a. Total execution time (tottime) spent in the given function is also shown in Fig.1b.

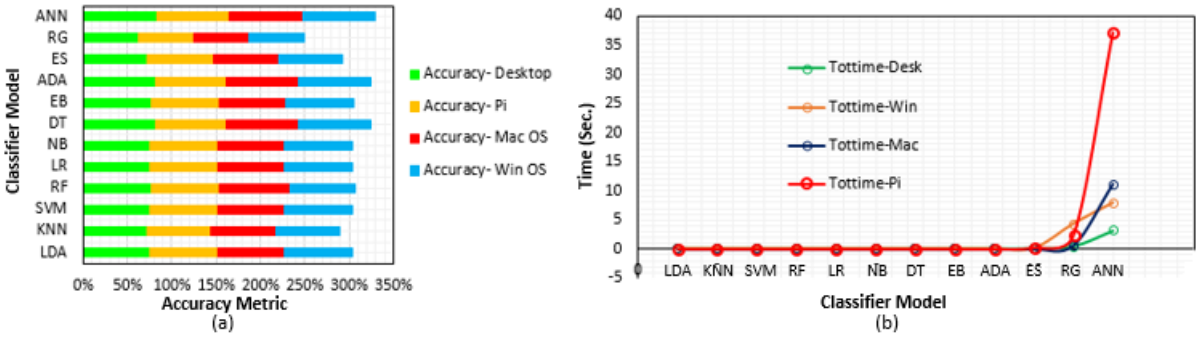

Figure 1. (a) Performance Evaluation on Pi, Laptop (Win & Mac OS) and Desktop (b) Total execution time of the Classifier Model profiling

Discussion: The present study demonstrates that RPi4 is a potentially viable device for low-cost BCI systems, but high-resource demanding classifiers such as ANN may need to be considered carefully in their implementation. The accuracy metric of ANN model achieved the best performance of 83% across all devices making 332% in total, followed by ADA and DT having 81% each, totaling 324% respectively. The total execution time for ANN is higher than the others, however RPi4 took more time to finish its task (which can further be investigated).

***Significance*:** Understanding the RPi4 profile while operating standard BCI procedures is important for the design of a low-cost high performance BCI control for real world applications to enable persons with severe disability.

References

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