Benchmark comparison of time-series algorithms on multivariate brain-data

Team 3: Shima Azizi, Kathleen Cachel, Alicia Howell, Amisha Jindal, Jocelyn Petitto

Introduction and Motivation

Datasets produced with fNIRS neuroimaging often defy Machine Learning ideals:

01	What?	• fNIRS data consists of multivariate time-series • Less than 10 instances of data per event for one participant usually • Intrinsic differences in how each participant's brain functions adds noise
02	Why?	• Time-series data is dependent on preceding data, and correlation between data points is lost in typical algorithms • Customized algorithms are univariate making it necessary to transform multivariate data to univariate, resulting in loss of information

Objective and Goals

- Evaluate and benchmark existing ML algorithms on fNIRS data
- Apply ML methods to a validated EEG dataset from UCI Archive to obtain a baseline
- Apply ML methods to a typical a fNIRS dataset and compare against the EEG results
- Measure the performances of algorithms using accuracy, time-efficiency, performance on varying sizes, and interpretability

Methodology

Compare 4 algorithms from the python library sk-time on three differently sized neuroimaging datasets - 2 EEG sets from UCI Archive (small and large) and one small dataset from the WPI HCI Lab

Algorithm	About
Time Series Forest Classifier	A modification of the random forest algorithm to the time series setting that employs a combination of entropy gain and a distance measure, referred to as the Entrance gain, for evaluating the splits [2,3].
Mr-SEQL	A univariate time series classifier that utilizes linear models (logistic regression) with features extracted from multiple symbolic representations of time series (SAX, SFA) using SEQL [2,4].
Bag of SFA Symbols Ensemble	Bag of SFA Symbols (BOSS) extracts “words” out of time-series data and builds features that represent the frequency of each word [2,5].
K Nearest Neighbors	This is an adapted version of the scikit-learn K-Neighbors classifier for time series data. It works on univariate times series only [2,6].

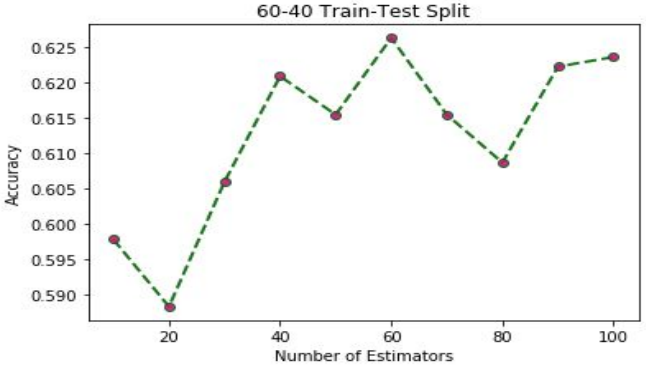
Time Series Forest Classifier

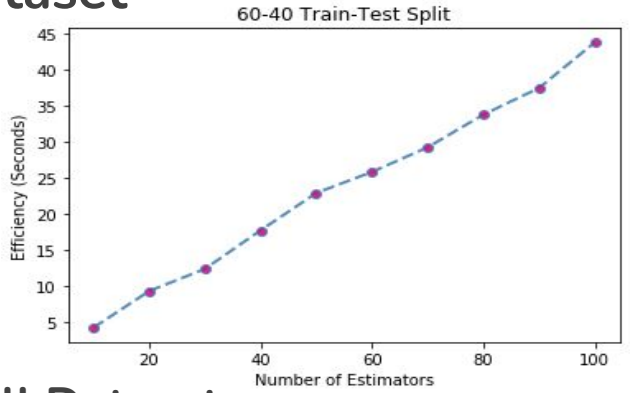
The best accuracies obtained with the algorithm are as follows:

Dataset	Accuracy	Efficiency	Parameters
UCI EEG Small Dataset	90.49%	105.36s	80-20 train-test split n_estimators = 100
UCI EEG Big Dataset	99.98%	126.09s	n_estimators = 5
fNIRS Dataset	63.04%	41.02s	60-40 train-test split n_estimators = 100

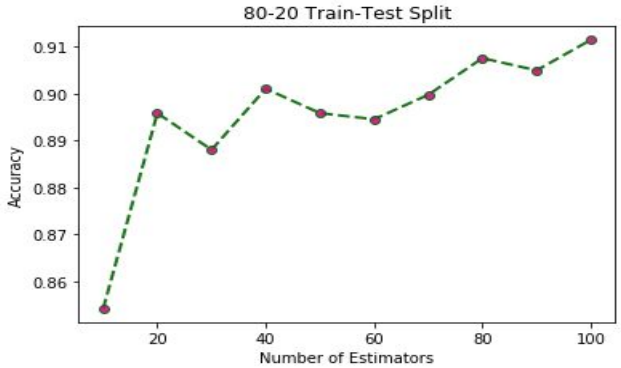
Time Series Forest Classifier

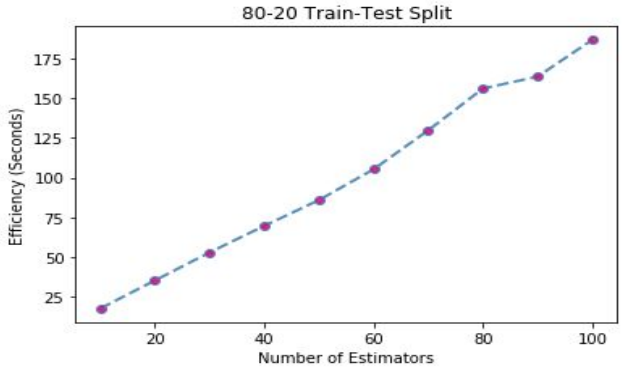
fNIRS Dataset





UCI EEG Small Dataset





Mr-SEQL

The best accuracies obtained with the algorithm are as follows:

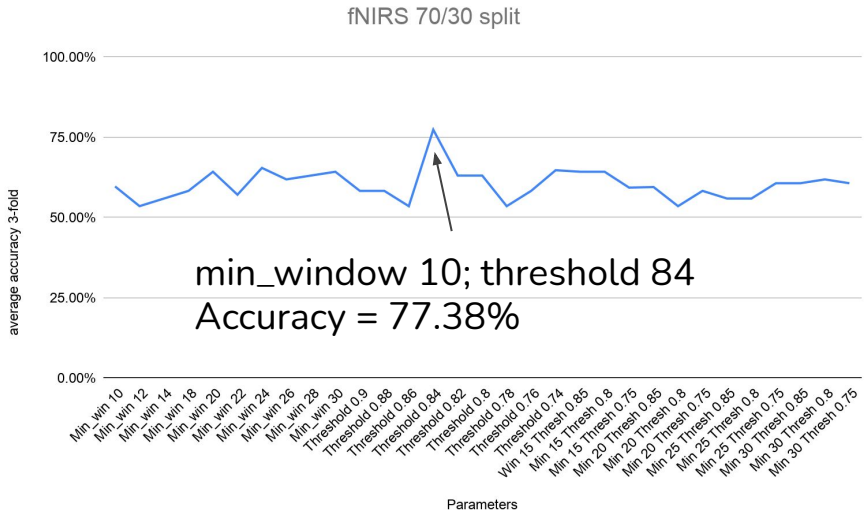
Dataset	Accuracy	Efficiency	Parameters
UCI EEG Small Dataset	36.19%	0.16s	80-20 train-test split seql_mode = “clf”
UCI EEG Big Dataset	33.33%	2.26s	seql_mode = “clf”
fNIRS Dataset	54.6%	0.03s	80-20 train-test split seql_mode = “clf”

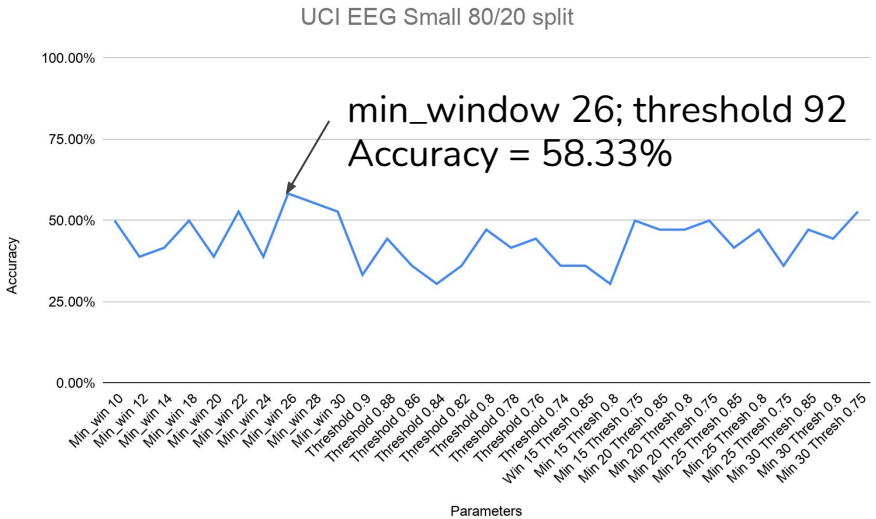
Boss Ensemble

The best accuracies with 3-fold validation obtained with the algorithm are as follows:

Dataset	Accuracy	Efficiency	Parameters
UCI EEG Small Dataset	58.33%	186.06s	80-20 train-test split min_window = 24; threshold = 0.92
UCI EEG Big Dataset	43.41%	7,484s	min_window = 10; threshold = 0.92
WPI fNIRS Dataset	77.38%	65.42s	70-30 train-test split min_window = 10; threshold = 0.84

Boss Ensemble Figures





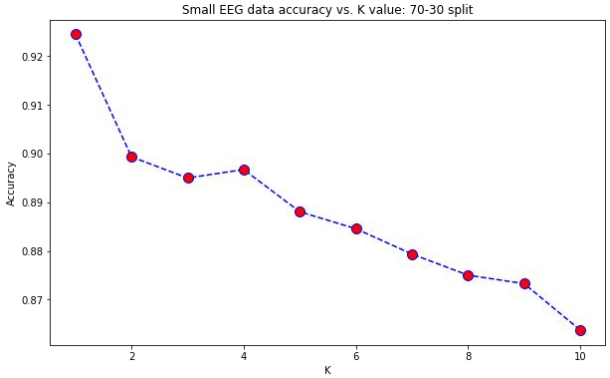
KNN

The best accuracies obtained with the algorithm are as follows:

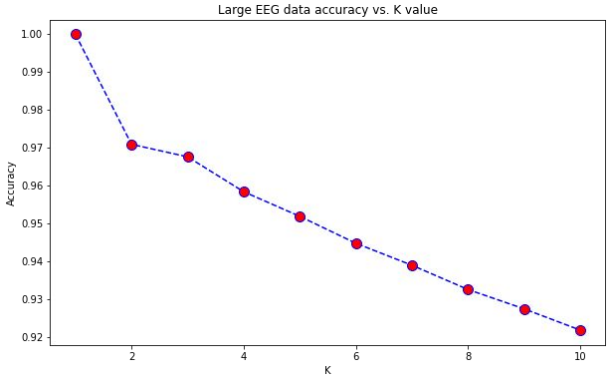
Dataset	Accuracy	Efficiency	Parameters
UCI EEG Small Dataset	93.50%	0.07s	70-30 train-test split; K = 1, default metric = ‘dtw’
UCI EEG Big Dataset	99.80%	1.28s	K = 1; default metric = ‘dtw’
fNIRS Dataset	65.58%	0.06s	70-30 train-test split; K = 1, default metric = ‘dtw’

KNN

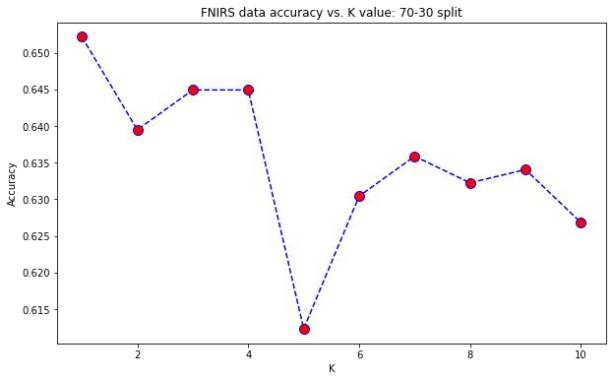
SMALL EEG DATA



LARGE EEG DATA

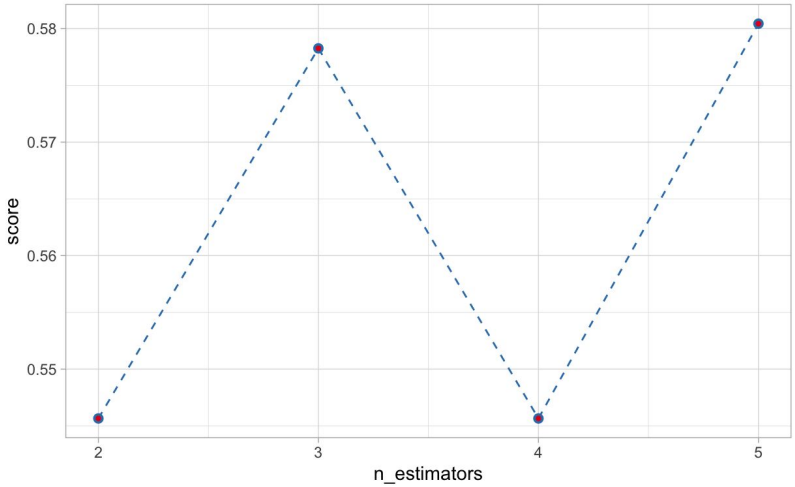


FNIRS DATA

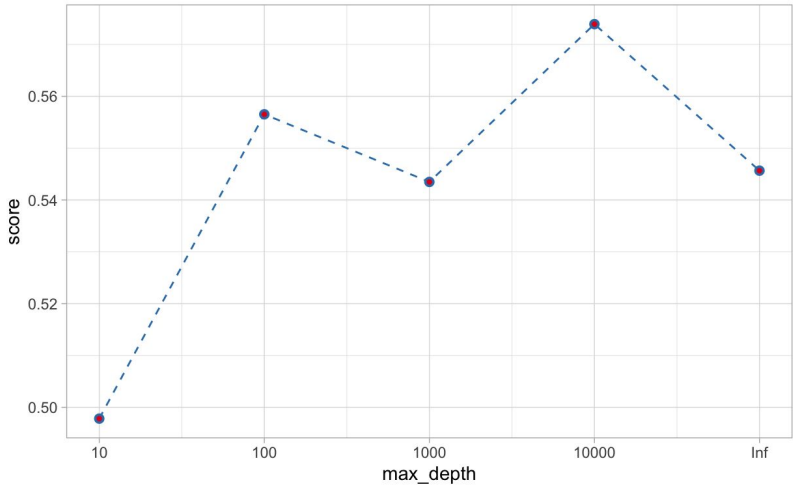


Proximity Forest

fNIRS 80/20 Split



fNIRS 80/20 Split



Defaults

n_estimators = 100

Max_depth = infinity

Recommendations

- KNN and TSF classifiers had the best accuracies on the UCI datasets
- BOSS Ensemble had the best accuracy for fNIRS data
- KNN was the most efficient on UCI data by several magnitudes
- Mr-SEQL was the most efficient on fNIRS data, but consistently had worst accuracy
- ~8% difference between KNN and BOSS accuracy
    - We recommend KNN as ideal generic neuroimaging algorithm, and BOSS for specifically small datasets

Thank you!