EIVIA 2025: Deep Learning for Time Series and Applications to Healthcare

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Healthcare Applications

Parkinson’s Diagnosis Based on Eye-Tracking Data

Parkinson's disease

- ❑ Incidence 83/10000 (+15% since 1990).
- ❑ Motor and cognitive symptoms.
- ❑ Diagnosis and prognosis methodology is not ideal.

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Our Goal:

Develop a quantitative methodology that can help medical doctors in diagnosis and prognosis.

The Dataset

- MEG and eye-tracking dataset recorded by **Josefine Waldthaler** and **Per Svenningson** from **Karolinska Hospital** in Stockholm.
- The dataset consists of 84 subjects, 54 non-demented patients with PD (stages 1-3) and 30 HC.
- Experiment in which two different data modalities are recorded:
  - MEG
  - Eye Tracking

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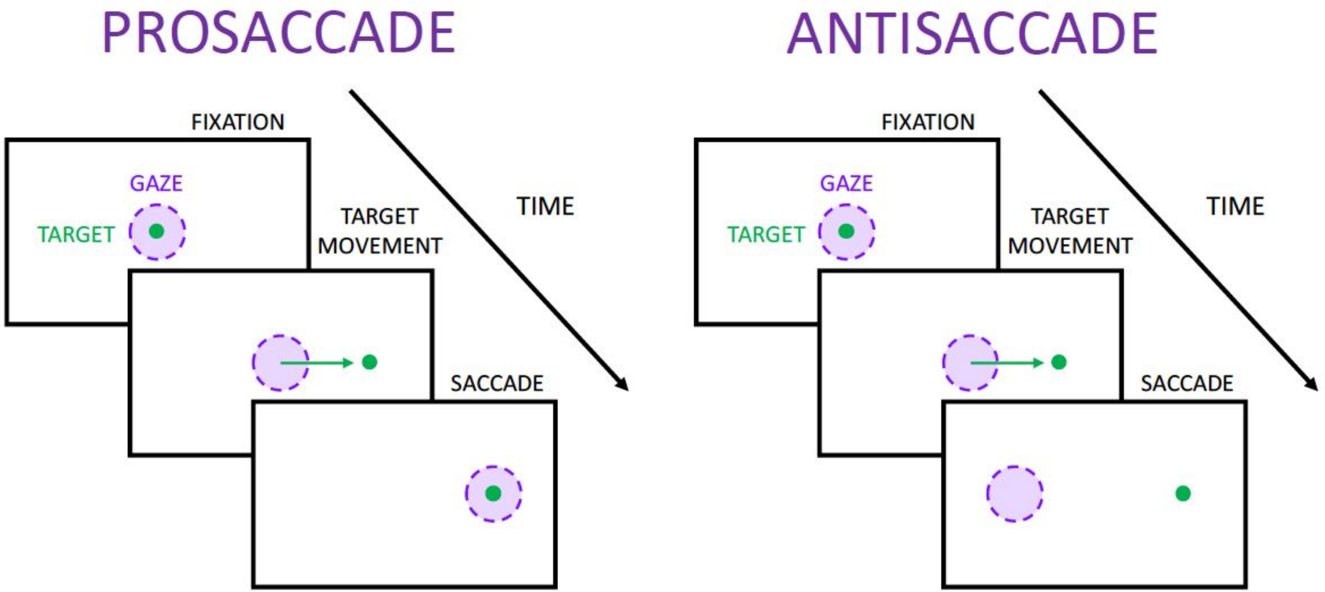
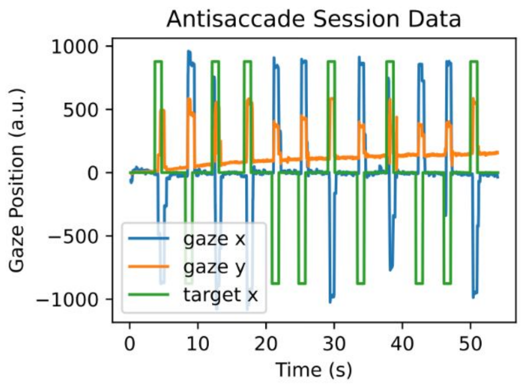
Experimental Protocol

The subjects perform a **Saccade** protocol.



Data description

We take **≈1.5s** segments corresponding to the **preparation phase** of one saccade or antisaccade event.



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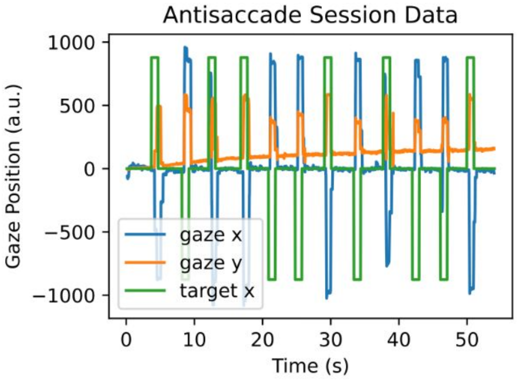

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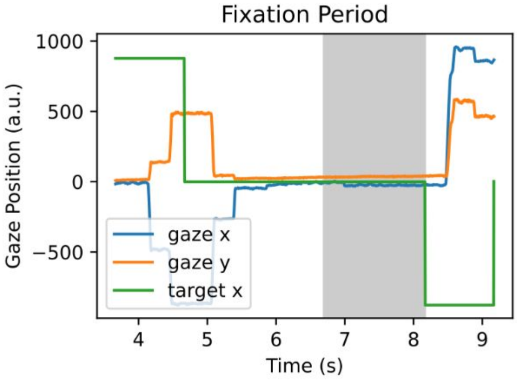

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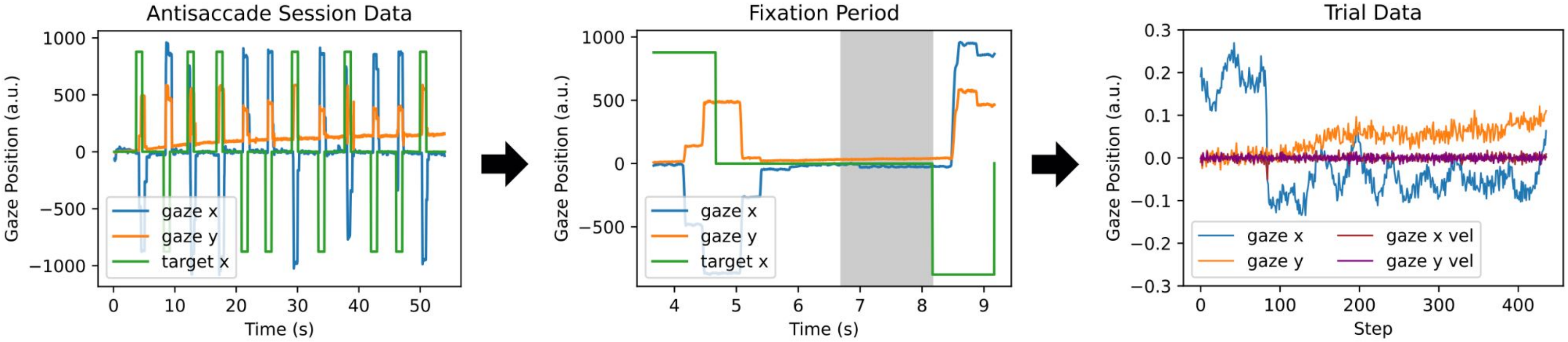

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4-dimensional time series

We have ≈**100** trials per subject

Data modality

We have **≈1.5s** segments of **eye movement** data corresponding to fixation moments during the experiment.

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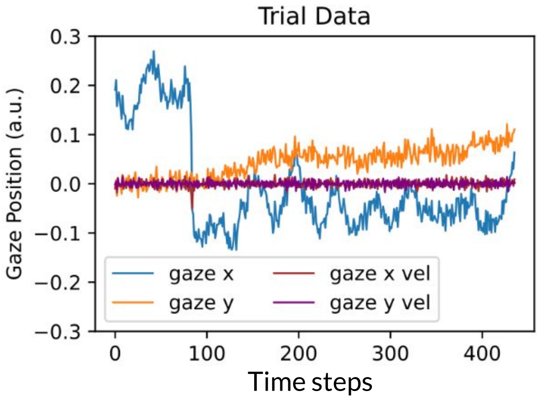

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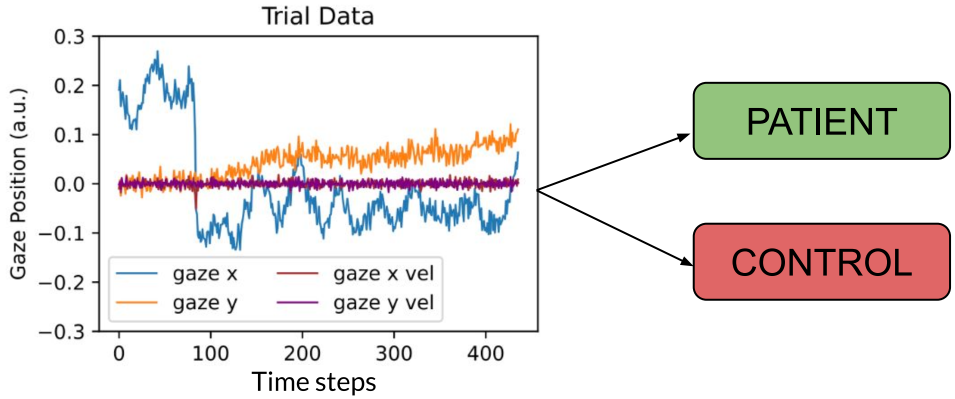

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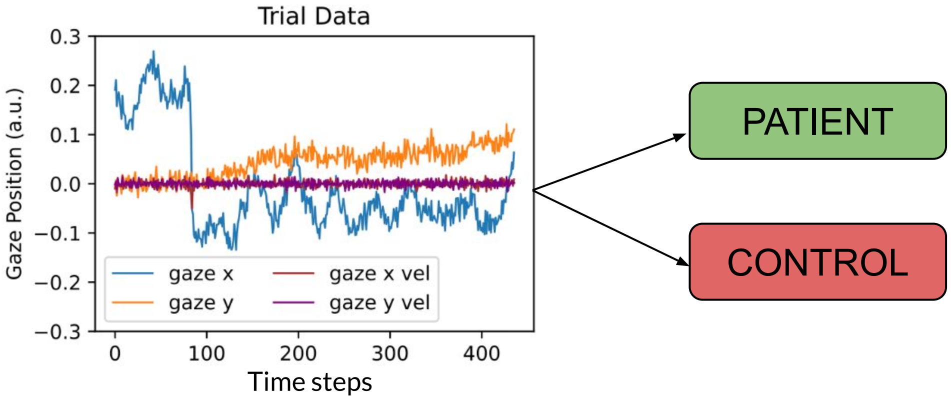

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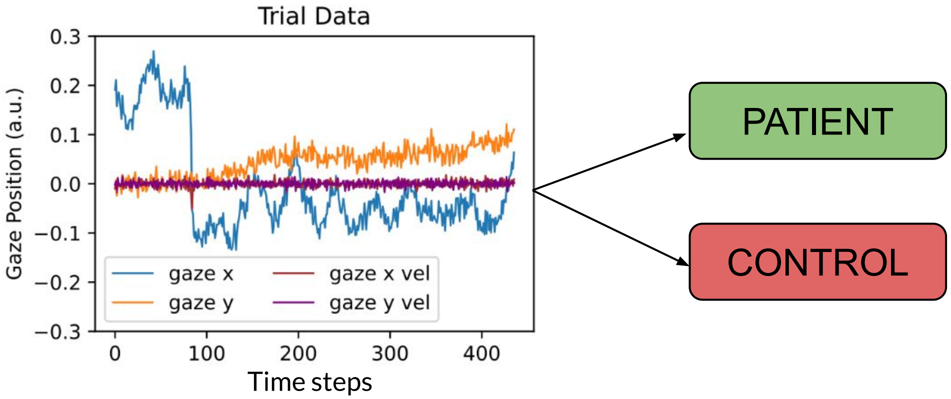

Time Series Classification (TSC) Problem

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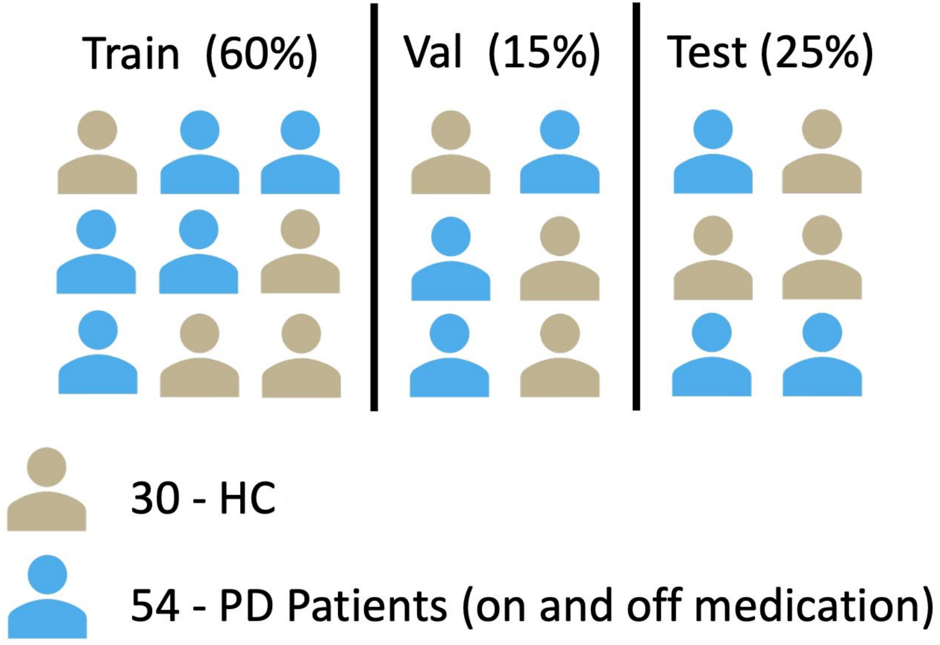
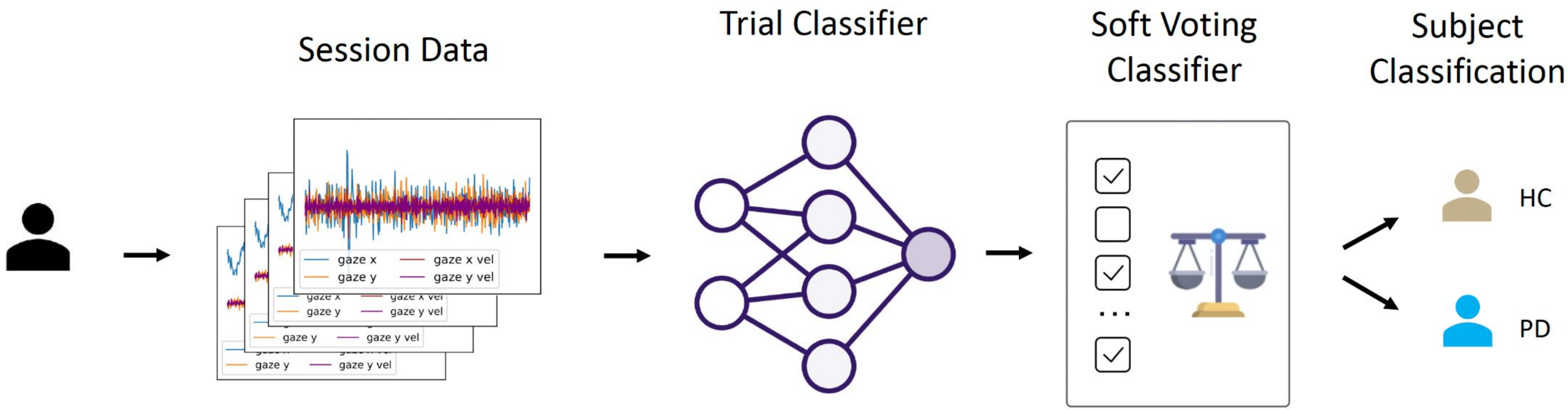
We need a proper TSC algorithm

Dataset Splitting



Inference Pipeline

Models are trained to perform a **trial classification**. We then aggregate all trials of one subject to perform a subject classification.

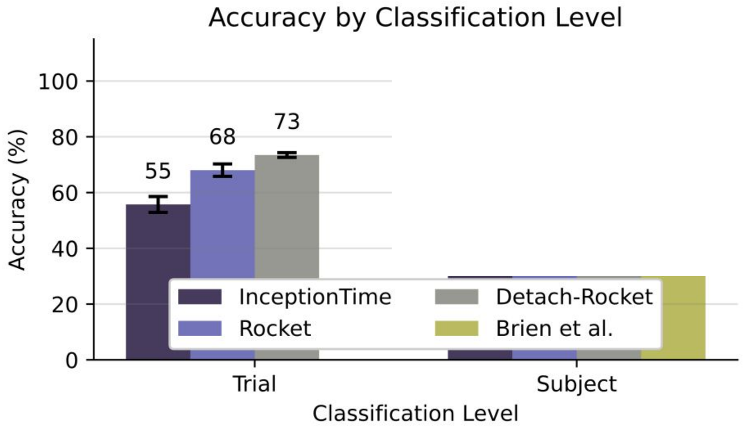


InceptionTime, **ROCKET** and **Detach-Rocket**

Classification Results

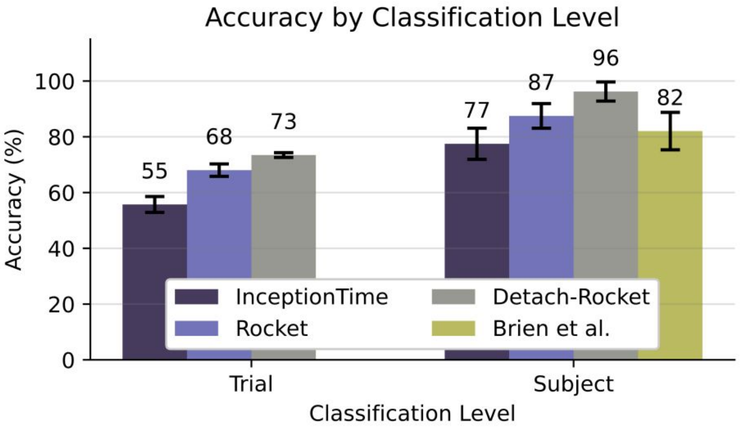
Model	Trial uF1-Score	Trial Accuracy
InceptionTime	0.52 ± 0.02	$55.73\% \pm 2.84\%$
ROCKET	0.63 ± 0.02	$68.04\% \pm 2.23\%$
Detach-ROCKET	$\mathbf{0.66} \pm 0.02$	$\mathbf{73.46\%} \pm 0.85\%$
Brien et al. (2023)		

Detach-ROCKET models retained, on average, merely 7% of the original number of features.



Classification Results

Model	Trial uF1-Score	Trial Accuracy	Subject uF1-Score	Subject Accuracy
InceptionTime	0.52 ± 0.02	$55.73\% \pm 2.84\%$	0.74 ± 0.04	$77.50\% \pm 5.59\%$
ROCKET	0.63 ± 0.02	$68.04\% \pm 2.23\%$	0.86 ± 0.04	$87.50\% \pm 4.42\%$
Detach-ROCKET	$\mathbf{0.66} \pm 0.02$	$\mathbf{73.46\%} \pm 0.85\%$	$\mathbf{0.96} \pm 0.04$	$\mathbf{96.25\%} \pm 3.42\%$
Brien et al. (2023)				$82\% \pm 6.7\%$



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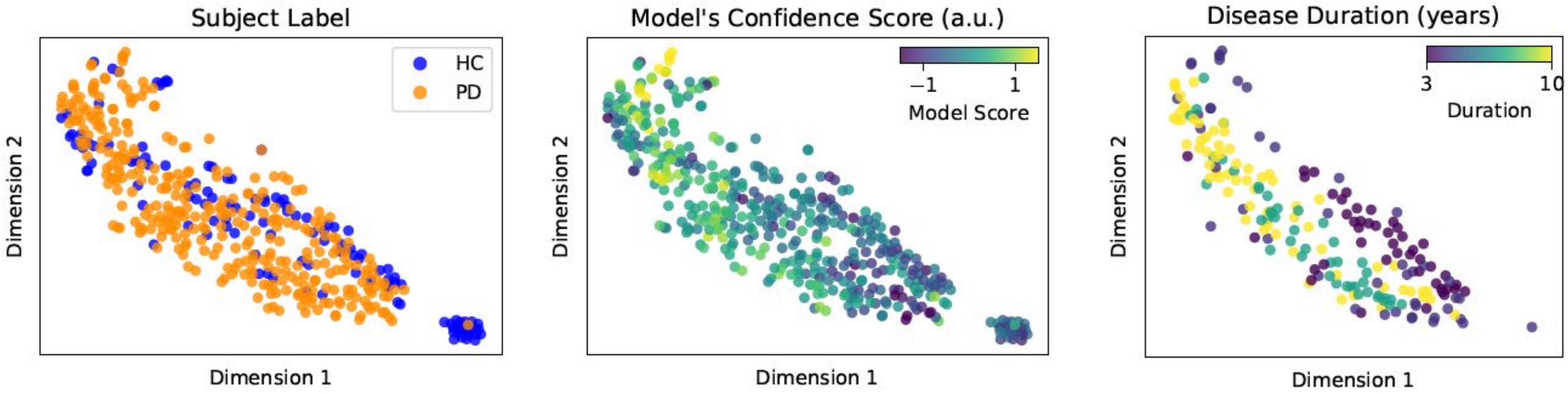

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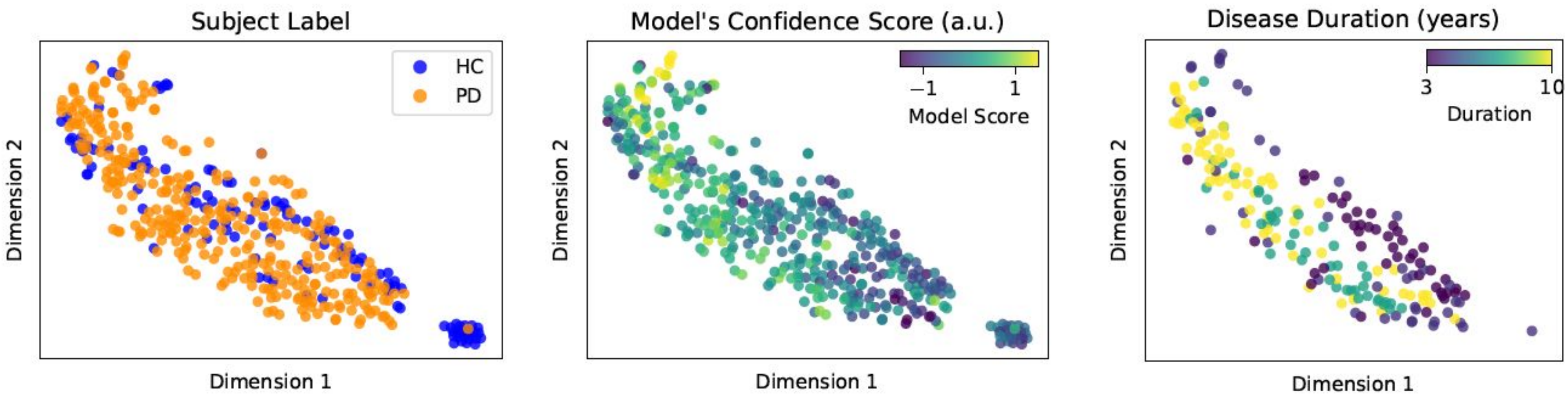


Correlation of **model confidence** with metadata of patients:

With **UDRS** (severity of symptoms)
[c=0.24, p= 0.0007 < 0.05]

Correlation

With **disease duration**
[c=0.17, p= 0.01 < 0.05]

Correlation

With **age** of patient
[c=-0.02, p= 0.6 > 0.05]

No Correlation

Brain Activity Data

Brain Activity Data

Brain activity measurements with non-invasive techniques:

- **EEG**: Measures electrical activity.

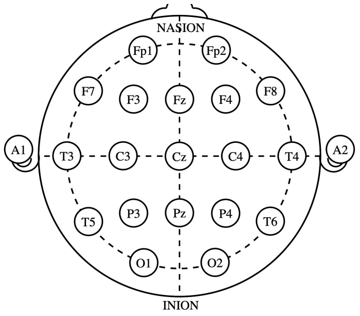
  Number of channels: ~**19-64**.

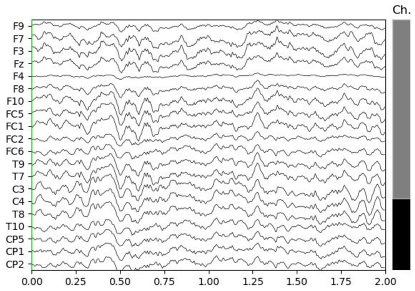
- **MEG**: Measures magnetic activity.

  Number of channels: ~**306**

- **fMRI**: Measures BOLD signal.

  Number of channels: ~**100,000** .





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Large number of channels (C)

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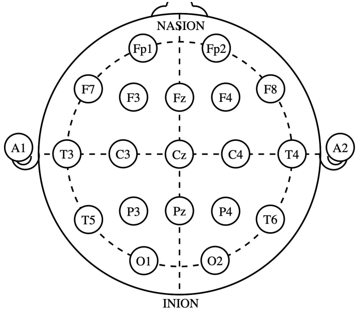

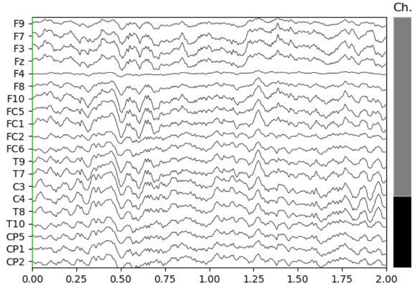

ROCKET Strengths and Weaknesses

- State-of-the-art performance for TSC
- Fast and simple training
- Less prone to overfitting (less parameters)

- It produces many features (many useless)
- Scales poorly with the number of channels
- Difficult to interpret

We need a very large number of kernels to have good coverage.

D-Rocket Ensemble for MTSC

ARTICLE

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Authors: Adrià Solana, Erik Fransén, Gonzalo Uribarri | Authors Info & Claims

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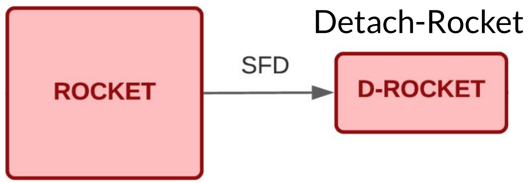

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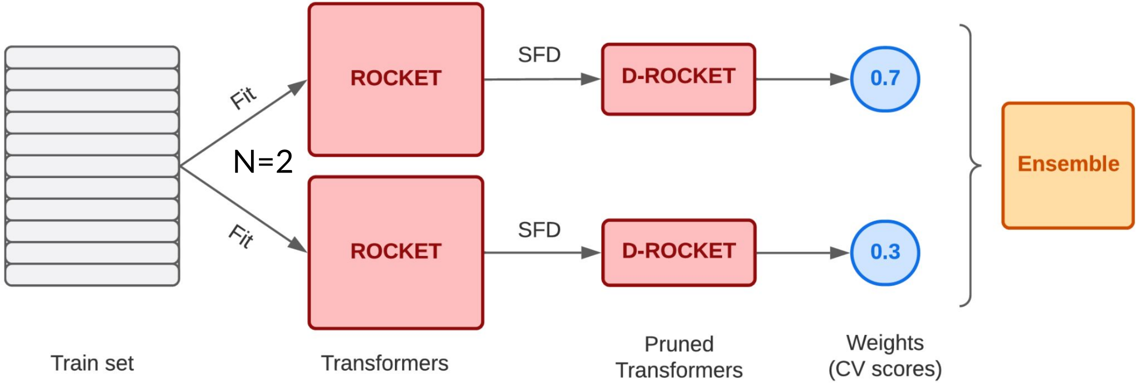

* Following the idea of Arsenal (part of HV2), Middlehurst et al. [2024]

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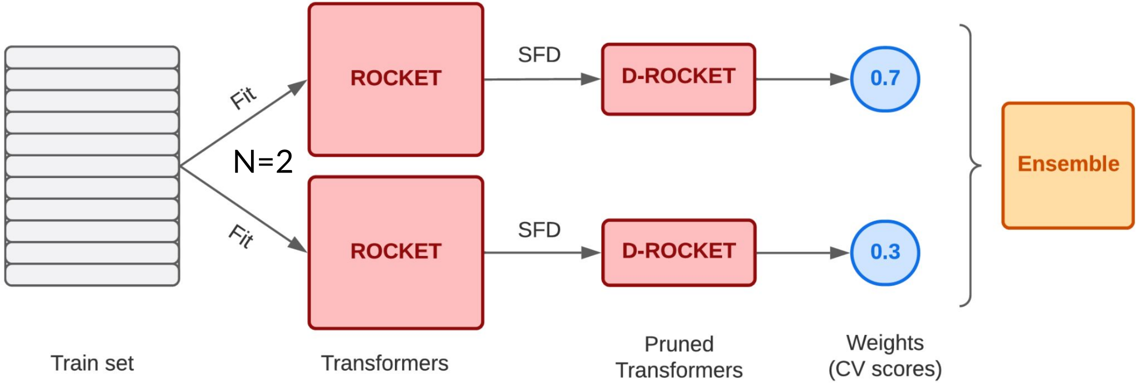

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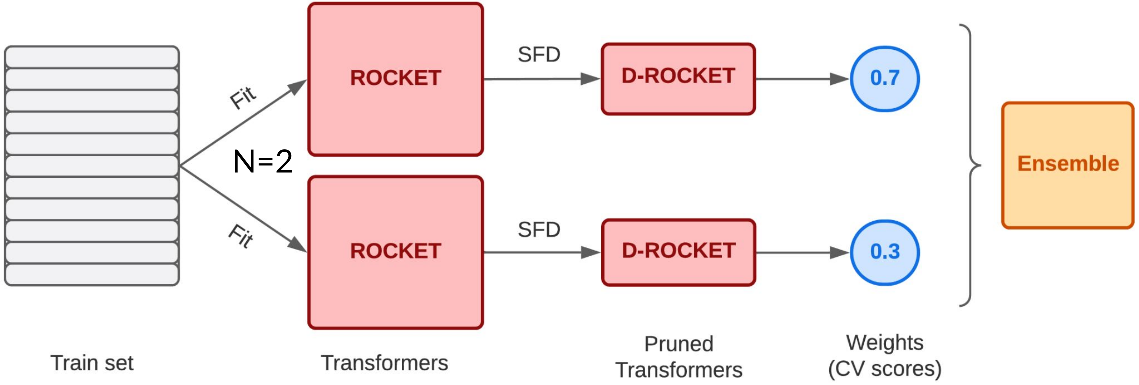

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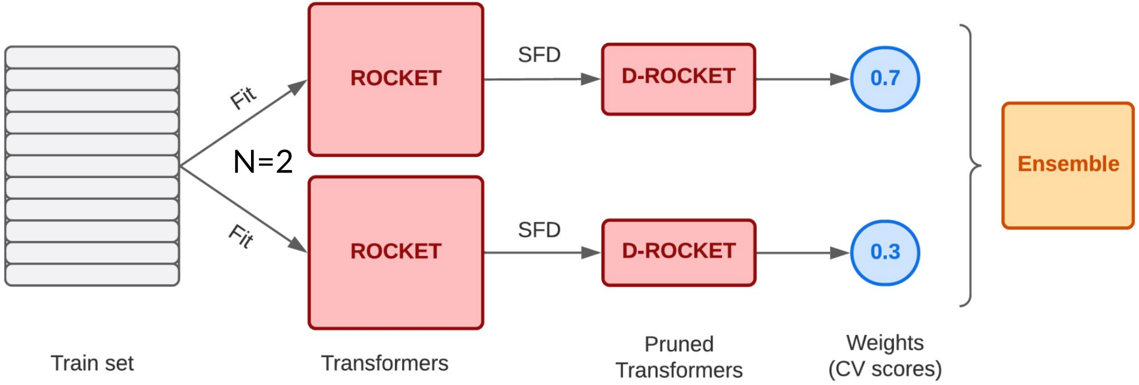

- Explores a large set of kernels.
- Provides channel relevance.
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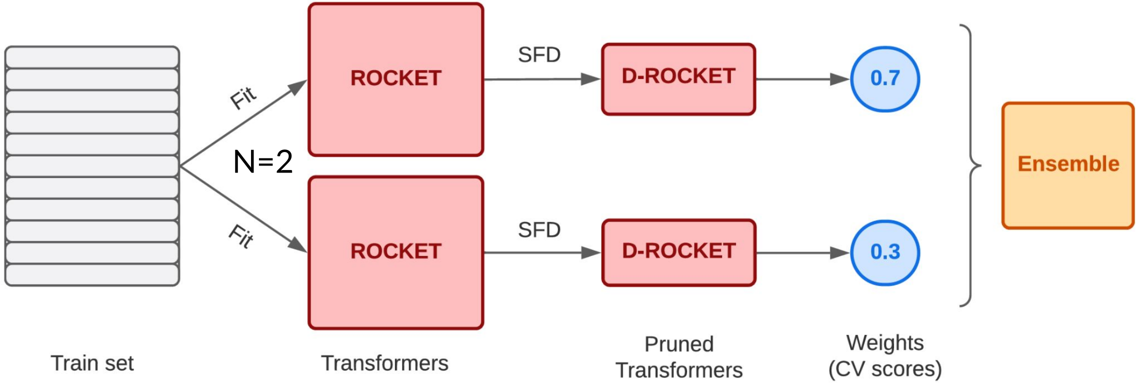

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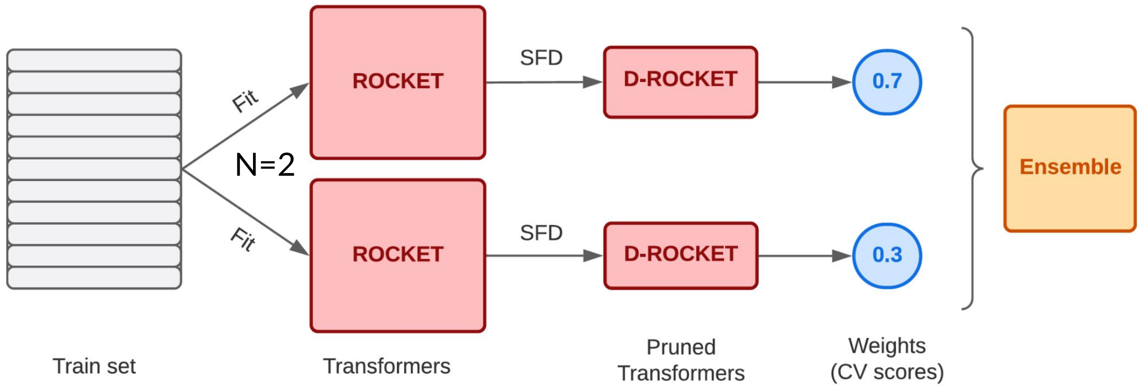

- 👍 Explores a large set of kernels.
- 👍 The resulting model is small.
- 👍 Provides channel relevance.
- 👍 Provides label probability! *
- 👎 Larger training time.

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Experiments: MEG Dataset

24 subject (16 train, 7 test) and **306 channels**. Classification task: is the subject observing a regular face or a scrambled face? *

* Henson et al. [2011]

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Model	**Train (%)**	**Test (%)**
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D-MiniRocket	72.2±2.9	60.8±0.5
Arsenal	87.4±0.1	61.5±0.4
D-Rocket Ensemble	78.6±0.3	**64.3±0.5**

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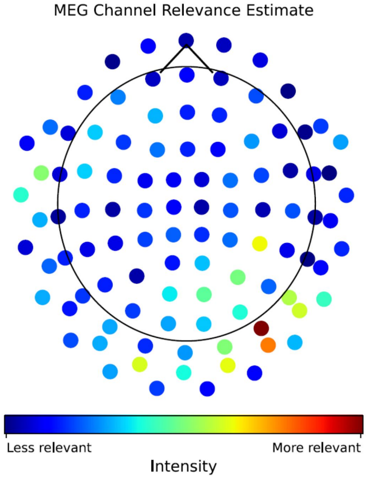

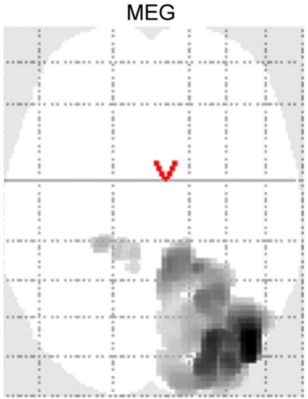

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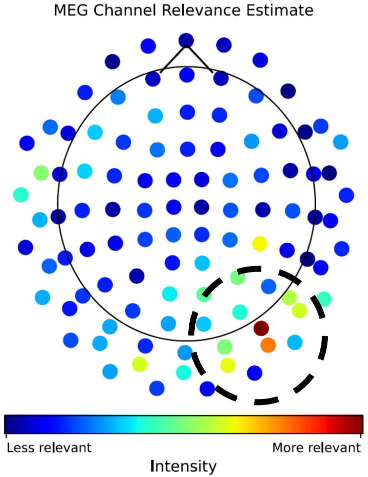

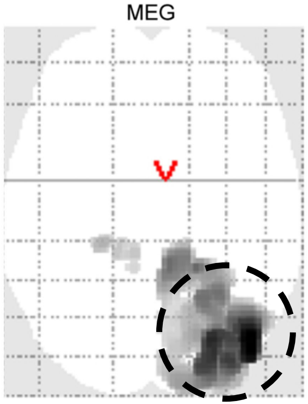

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We find the same relevant area

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Experiments: EEG Dataset

65 subject (LOSO CV) and **19 channels**. Classification task: is the subject a patient with **Alzheimer's Disease or a Healthy Control**?

* Networks trained with SGD

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Type	AD/CN model	ACC	SENS	SPEC	PREC	F1
Feature engineering	LightGBM	76.28%	76.08%	76.52%	79.67%	77.83%
	XGBoost	75.53%	76.08%	74.87%	78.55%	77.29%
	CatBoost	75.39%	75.50%	75.25%	76.68%	77.05%
	SVM+PCA	73.75%	71.51%	76.46%	78.60%	74.89%
	PCA-kNN	72.52%	70.30%	75.19%	77.41%	73.69%
	MLP *	73.69%	72.98%	74.81%	77.80%	75.31%
	DICE-net [18] *	83.28%	79.81%	87.94%	88.94%	84.12%
Raw EEG	EEGNet [15] *	41%	47.20%	37.67%	37.89%	42.04%
	EEGNetSSVEP [28] *	51.46%	56.78%	45.39%	47.65%	51.82%
	DeepConvNet [23] *	54.21%	45.43%	57.59%	48.71%	47.01%
	ShallowConvNet [23] *	42.18%	46.50%	41.11%	49.74%	48.07%
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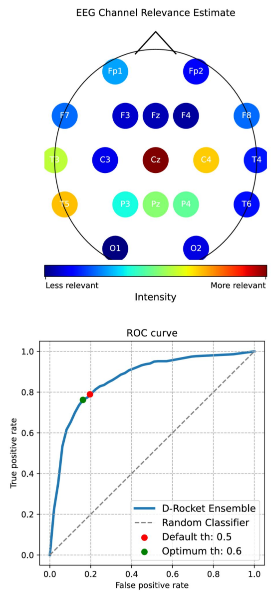
Interpretability:



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Hands-on Time: Notebook 5

Detach-ROCKET

ROCKET models

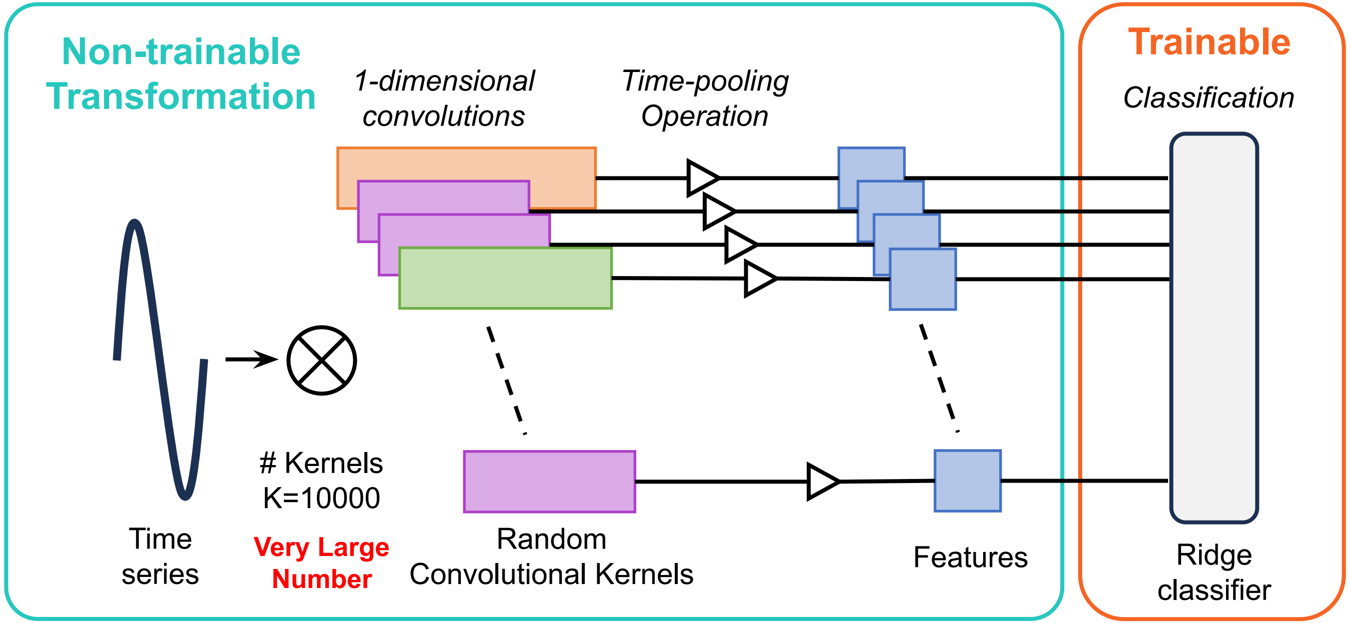
Random Convolutional Kernel Transform (ROCKET)* is a **transformation stage** which can be applied to **time-series data.**

This is KEY!

ROCKET
Kernels: Random
Pooling: MAX + PPV
 # Features: 20000

MiniRocket
Kernels: Dictionary
Pooling: PPV
 # Features: 10000

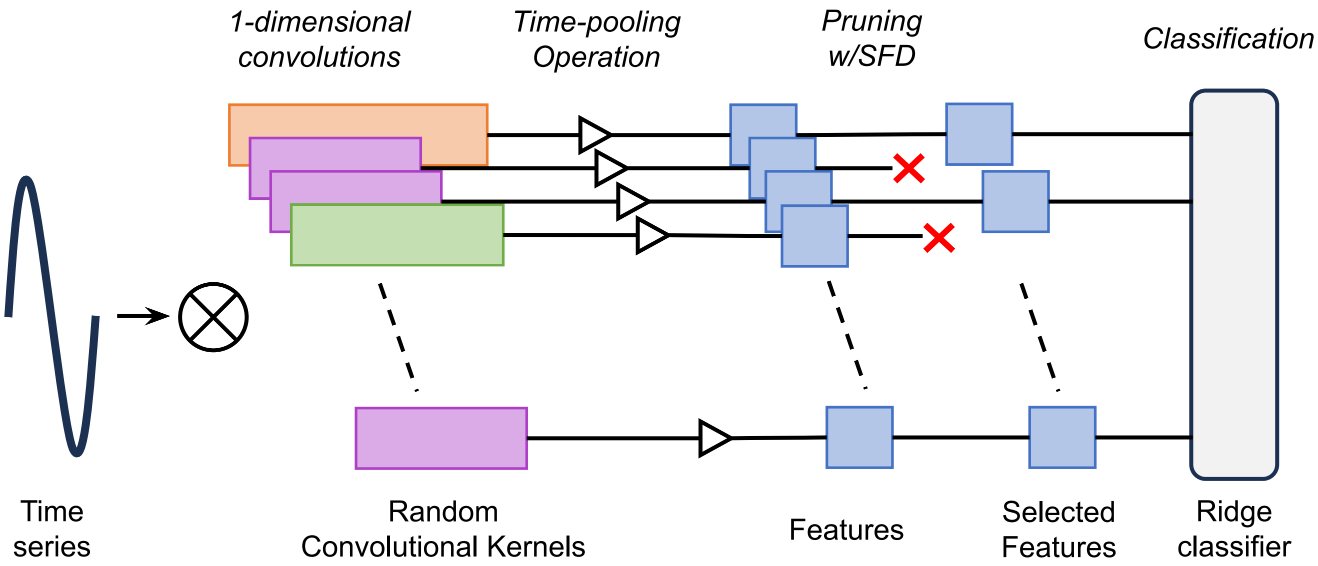
MultiRocket
Kernels: Dictionary
Pooling: PPV+MPV+MIPV+LSPV
 # Features: 50000



* Dempster et al. [2020]

Pruning ROCKET with SFD

We propose an algorithm to select the most relevant features called Sequential Feature Detachment (SFD)*.



* Recently published in Data Min. Knowl. Discov., Uribarri et al. [2024]