DEEPHEALTH

Use Case 13

Lab 3: Epileptic Seizure Detection

Winter School 25/01/2022

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 825111.

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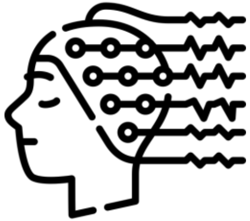
Epilepsy Detection

Introduction

- Epilepsy
  - Neurological disorder characterized by **recurrent seizures**
  - Episodes of **involuntary movement**
  - Around **50 million** people diagnosed in the world



- Electroencephalogram (**EEG**)
  - Recording the **electrical activity** of the brain
  - **Electrodes** located on the scalp
  - Continuous **signal** composed of different channels

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Epilepsy Detection

Brain stages

Interictal

Normal activity.

Pre-ictal

Strange brain activity, usually before an actual seizure.

Ictal

Period while a patient is suffering a seizure.

Post-Ictal

The patient is recovering from a seizure.

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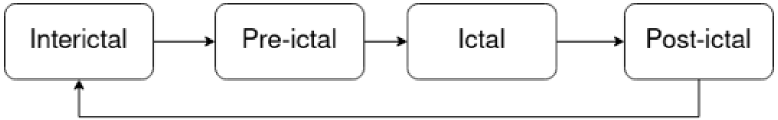
Epilepsy Detection

Brain Stages

- General cycle of stages



- Automatic **seizure detection** task (not prediction few minutes before seizures)

Class 0

Interictal + Pre-ictal + Post-ictal

Class 1

Ictal

- **High variability** between subjects
  - **Patient-Dependent** classifiers

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Dataset

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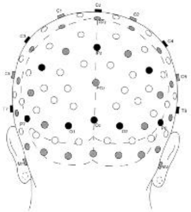
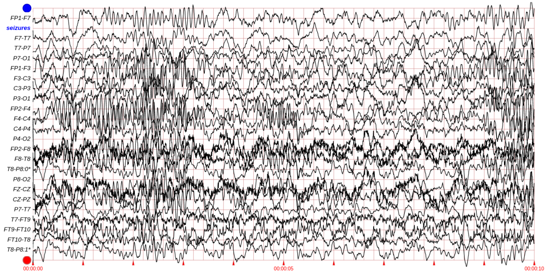
Dataset

Data description

- **CHB-MIT Scalp EEG Database** from [Physionet]
- EEG recordings from **24 pediatric subjects**
- Data in **EDF** (European Data Format)
- Sessions are between **24 and 48 hours** long, split in several files
- Most files are **1 hour long,** others are longer (up to four hours)
- Electrodes located on the scalp (10-20 system standard)
- **23 channels**, related to pairs of electrodes
- Acquired at **256 Hz**
- **Manual Labelling**: Starting and Ending times of seizures





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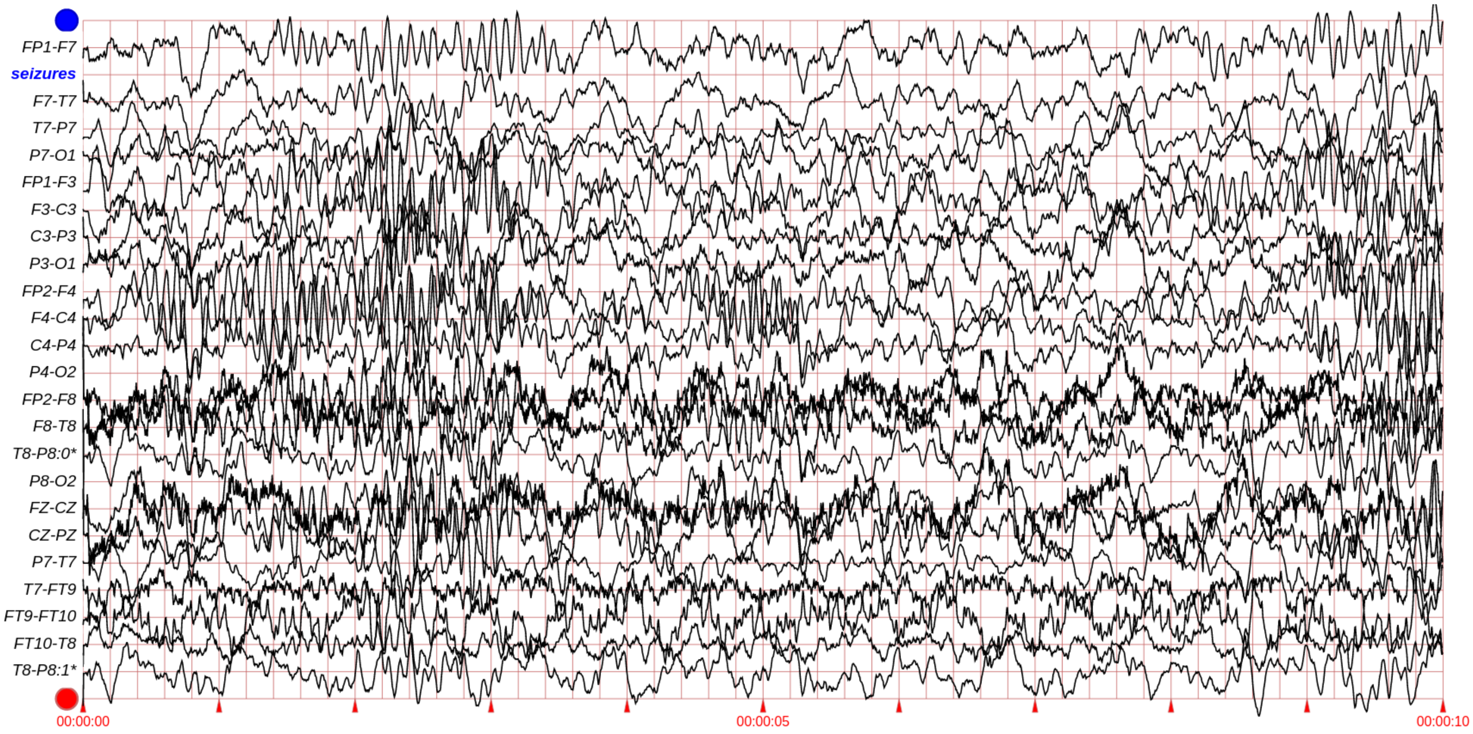
Dataset

Data description



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Dataset

Data preparation, cleaning and selection

- Preparation preprocess (Data cleaning process done by Winter-School team):
    1. Read signals from EDF format
    2. Homogenize signals to have each channel in the same position
    3. Store the data in a Python dictionary (containing signals and seizure information)
    4. Serialize the object in Pickle to save it (.pbz2 files)

- We provide a subset of the original dataset already cleaned

```
clean_signals/
├── chb01/
├── chb03/
├── chb05/
└── ...
```


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Dataset

Splits

Train	Validation	Test
65 %	**15 %**	**20 %**
31,2 hours	7,2 hours	9,6 hours

A whole session of 48 hours

Splits not in chronological order

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Dataset

Class imbalance

Seizures normally last few seconds, so there is a high class imbalance.

Patient id	# files without seizures	# files with seizures	# interictal hours	# ictal hours
chb01	35	7	40,43	0,12
chb03	31	7	37,89	0,11
chb05	34	5	38,85	0,16
chb08	15	5	19,75	0,26
chb12	11	10	20,41	0,28
chb14	19	7	25,95	0,05
chb15	25	14	38,46	0,55
chb24	10	12	21,15	0,14
Total	**180**	**67**	**242,89**	**1,67**

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Recurrent Approach

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Recurrent Approach

- Recurrent Neural Networks
  - LSTM / GRU layers
- Data Loader
- Post inference process
- Metrics
  - Neural Network Metrics
  - Post inference Metrics
- Results

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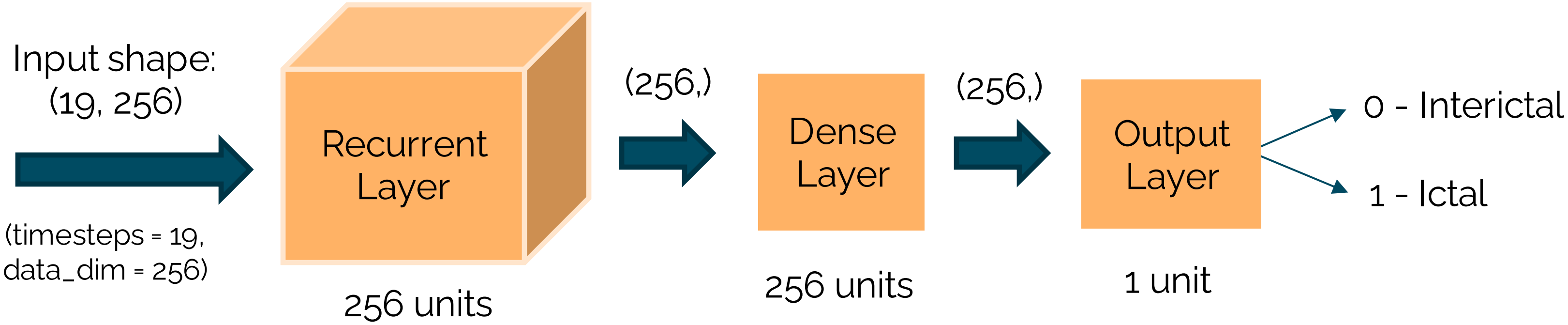
Recurrent Approach

RNN topologies based on LSTM and GRU layers



In the first example provided we are using **19** timesteps of one-second-long sliding windows, that is why the input shape is **(19, 256)**. Because each one of the 23 channels is processed independently.

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Recurrent Approach

Data Loader

- Data Loader Sequence Parameters
  - window_length (in seconds)
  - shift (in seconds)
  - timesteps

```
dg = RawRecurrentDataGenerator(index_filenames=['../indexes_detection/chb01/test.txt'],
                               window_length = 1, # in seconds
                               shift = 0.5, # in seconds
                               timesteps = 19, # in seconds
                               sampling_rate = 256, # in Hz
                               batch_size = 10,
                               do_standard_scaling = True,
                               in_training_mode = True,
                               balance_batches = True,
                               patient_id = 'chb01')
```


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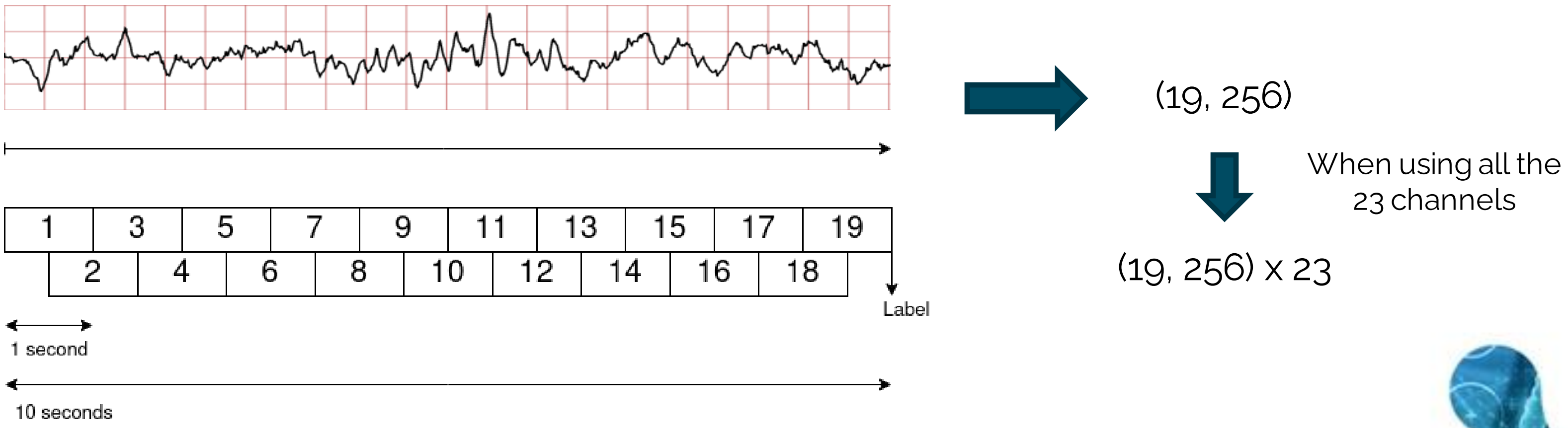
Recurrent Approach

Data Loader - Example

- Example of sequence generation
  - window_length = 1 second
  - shift = 0.5 seconds
  - timesteps = 19



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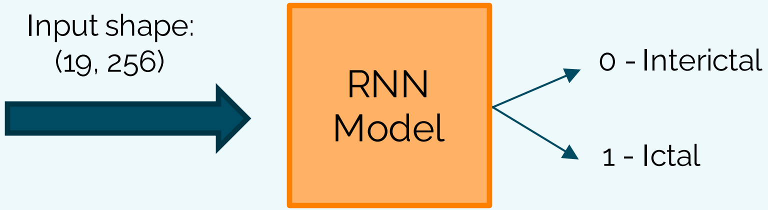
Recurrent Approach

Data Loader - Example

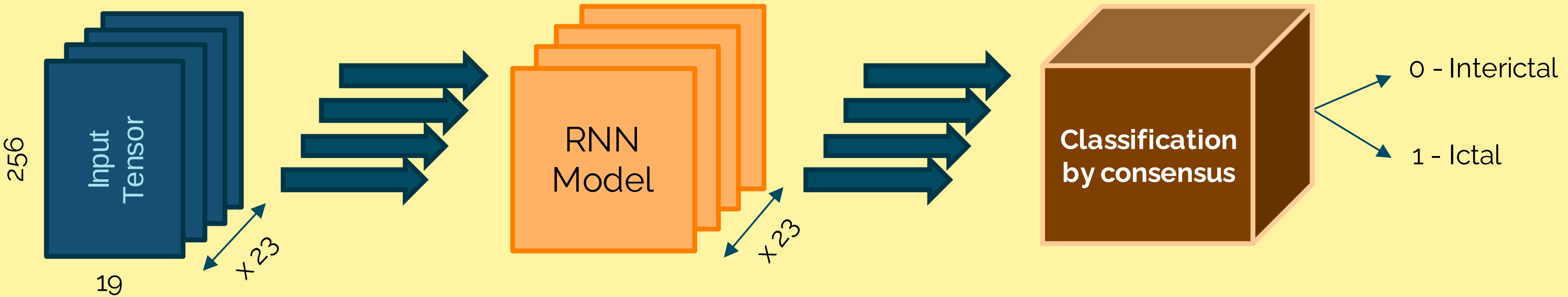
Training Mode

(19, 256) x 23

We independently pass each channel through the net



Inference Mode



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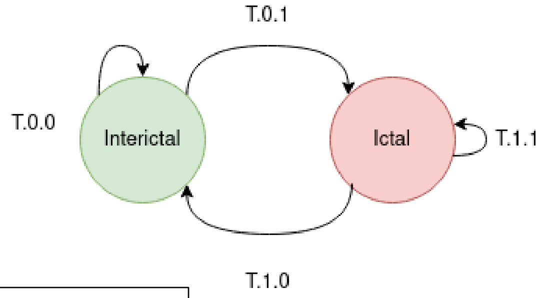
Recurrent Approach

Post inference process

- Post inference function to act as a detector
  - Analyses the consecutive outputs
  - Raises alarms when it detects a seizure



Detection threshold

Ground Truth	... 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 ...
Prediction	... 0 0 0 0 1 0 0 0 0 1 1 1 1 1 1 1 0 1 1 0 0 0 0 0 1 1 0 1 0 0 0 0 ...

Post-Inference window

Inference window length

If the proportion of ones inside the post-inference window while being in the **Interictal** state is greater than **alpha_pos,** it makes the transition from Interictal to Ictal: T.0.1

If the proportion of ones inside the post-inference window while being in the **Ictal** state is lower than **alpha_neg,** it makes the transition from Ictal to Interctal: T.1.0

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Recurrent Approach

Metrics

Classifier Metrics

- Accuracy
- Macro F1-score
- Balanced Accuracy

- Metrics at two levels
  - Channel independent
  - Ensemble: all 23 channels combined

Post Inference process Metrics

- Post-inference window accuracy
- Percentage of detected seizures
- Average Latency (in seconds)
- False Alarms per hour

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Recurrent Approach

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Results

Experiment configuration

Window Length (s)	Shift (s)	Timesteps	Model	Optimizer	Initial LR	Epochs
1	0,5	19	GRU	Adam	0,0001	10

Post-Inference Parameters

Post-Inference Window Length (in timesteps)	Alpha_pos	Alpha_neg	Detection Threshold (s)
20	0,4	0,4	20

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Recurrent Approach

	Test						Post-Inference Process with Test subset					
	Channel Independent			Combined channels								
Patient	Acc	F1-Score	Balanced Acc	Acc	F1-score	Balanced Acc	Acc	# Seizures	Detected seizures	Latency (s)	False Alarms per Hour	Hours
chb01	99,75%	0,8828	86,34%	99,93%	0,9667	94,45%	99,90%	2	100,00%	11,75	0,00	9,62
chb03	99,62%	0,6117	57,53%	99,64%	0,4991	50,00%	99,64%	2	0,00%	-	0,00	8,97
chb05	99,75%	0,8553	87,35%	99,90%	0,9335	88,46%	99,87%	1	0,00%	-	0,13	7,98
chb08	97,60%	0,7215	83,11%	99,49%	0,9054	87,71%	99,49%	1	100,00%	18,00	0,80	4,99
chb12	95,26%	0,5774	63,09%	97,63%	0,6018	58,85%	97,53%	11	54,55%	13,92	2,67	5,98
chb14	99,76%	0,5856	58,21%	99,85%	0,5252	51,32%	99,85%	2	0,00%	-	0,00	6,98
chb15	96,70%	0,6383	67,83%	97,86%	0,6363	61,32%	97,71%	7	28,57%	11,75	1,89	8,98
chb24	99,34%	0,7385	69,23%	99,49%	0,7586	67,56%	99,44%	4	100,00%	11,50	0,16	6,28

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Convolutional Approach

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Convolutional Approach

- Time Delay Convolutional Neural Networks
- Post Inference Process
- Metrics
  - Neural Network Metrics
  - Post inference Metrics
- Results

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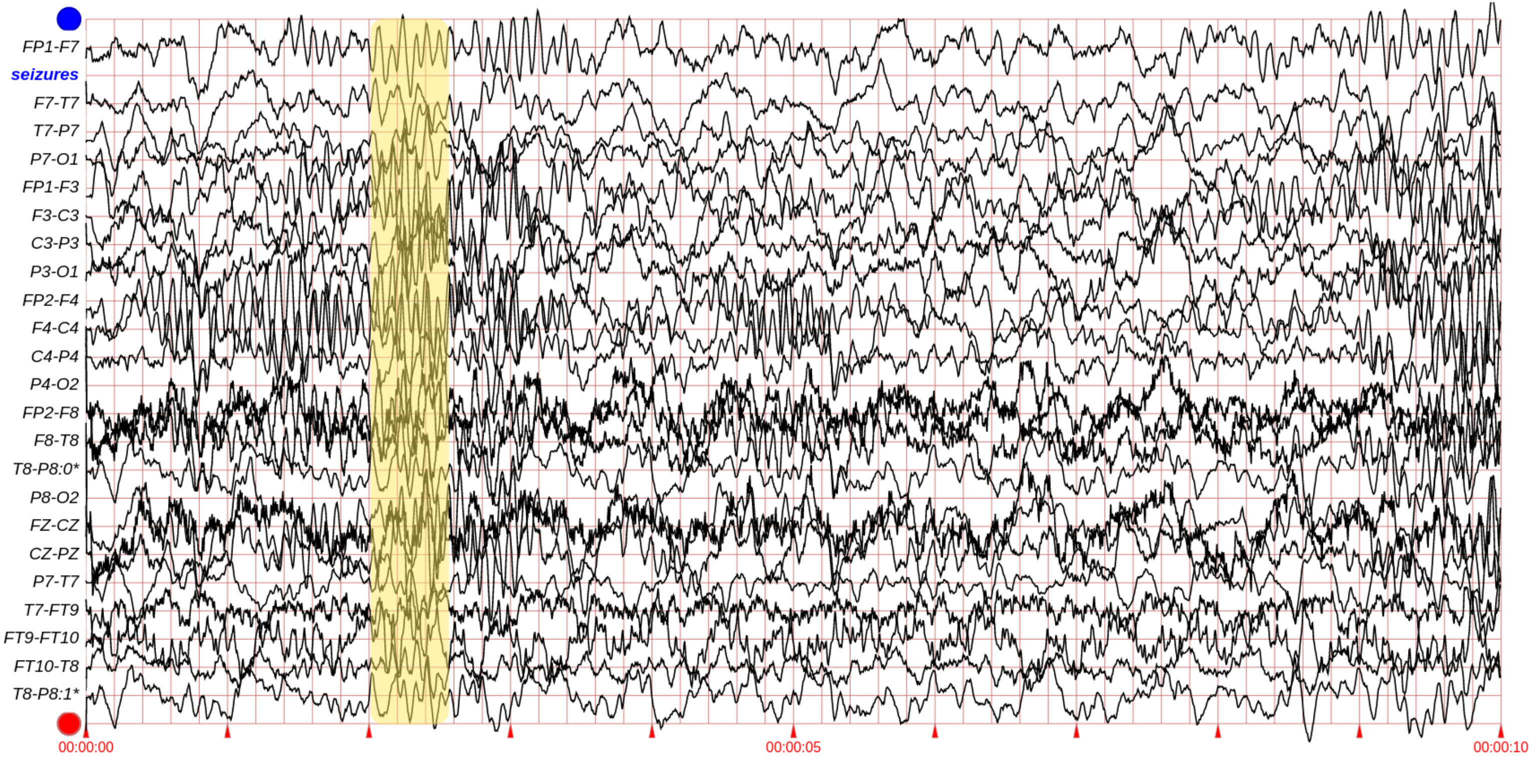
Convolutional Approach

Time Delay Convolutional Neural Networks

Kernel_size = (128, 23), strides = (64, 1) --> 500 ms long window shifted every 250 ms

Input shape: (2560, 23)



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Convolutional Approach

- Models available in the pipeline
  - "conv1"

- Post Inference Process
- Metrics
  - Neural Network Metrics
  - Post inference Metrics

The same as in the recurrent approach

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Convolutional Approach

Results

Experiment configuration

Window Length (s)	Shift (s)	Model	Optimizer	Initial LR	Epochs
10	0,25	Conv1	Adam	0,00001	10

Post-Inference Parameters

Post-Inference Window Length (in timesteps)	Alpha_pos	Alpha_neg	Detection Threshold (s)
20	0,4	0,4	20

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Convolutional Approach

	Test			Post-Inference Process with Test subset					
Patient	Acc	F1-score	Balanced Acc	Acc	# Seizures	Detected seizures	Latency (s)	False Alarms per Hour	Hours
chb01	99,72%	0,8940	96,15%	99,69%	2	100,00%	9,00	0,73	9,62
chb03	99,62%	0,8086	91,86%	99,56%	2	100,00%	2,88	1,78	8,98
chb05	99,66%	0,8330	92,07%	99,59%	1	0,00%	-	1,76	7,98
chb08	99,2%	0,8477	81,74%	99,19%	1	100,00%	16,75	1,80	4,99
chb12	96,73%	0,5530	55,63%	96,51%	11	45,45%	15,90	7,52	5,98
chb14	98,83%	0,4971	49,49%	98,71%	2	0,00%	-	4,01	6,98
chb15	97,63%	0,7848	94,28%	97,52%	7	57,14%	10,44	3,01	8,98
chb24	99,22%	0,6435	60,05%	99,23%	4	75,00%	9,25	0,96	6,28

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Conclusions

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Conclusions

Conclusions of the results

- We did not find an **ideal model** that works well with every patient
- In general, **slightly better accuracy** with the convolutional approach
- In some cases, the **recurrent approach** has more latency but less false alarms, and the **convolutional approach** has lower latency but more false alarms per hour.

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Resources

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Resources

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Original Dataset

CHB-MIT Scalp EEG Database

Prepared Dataset

clean_signals.zip (7.6 GB) Option 1 Option 2

Pipeline Repository

UC13_pipeline

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Thank you!

Javier Martínez Bernia

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