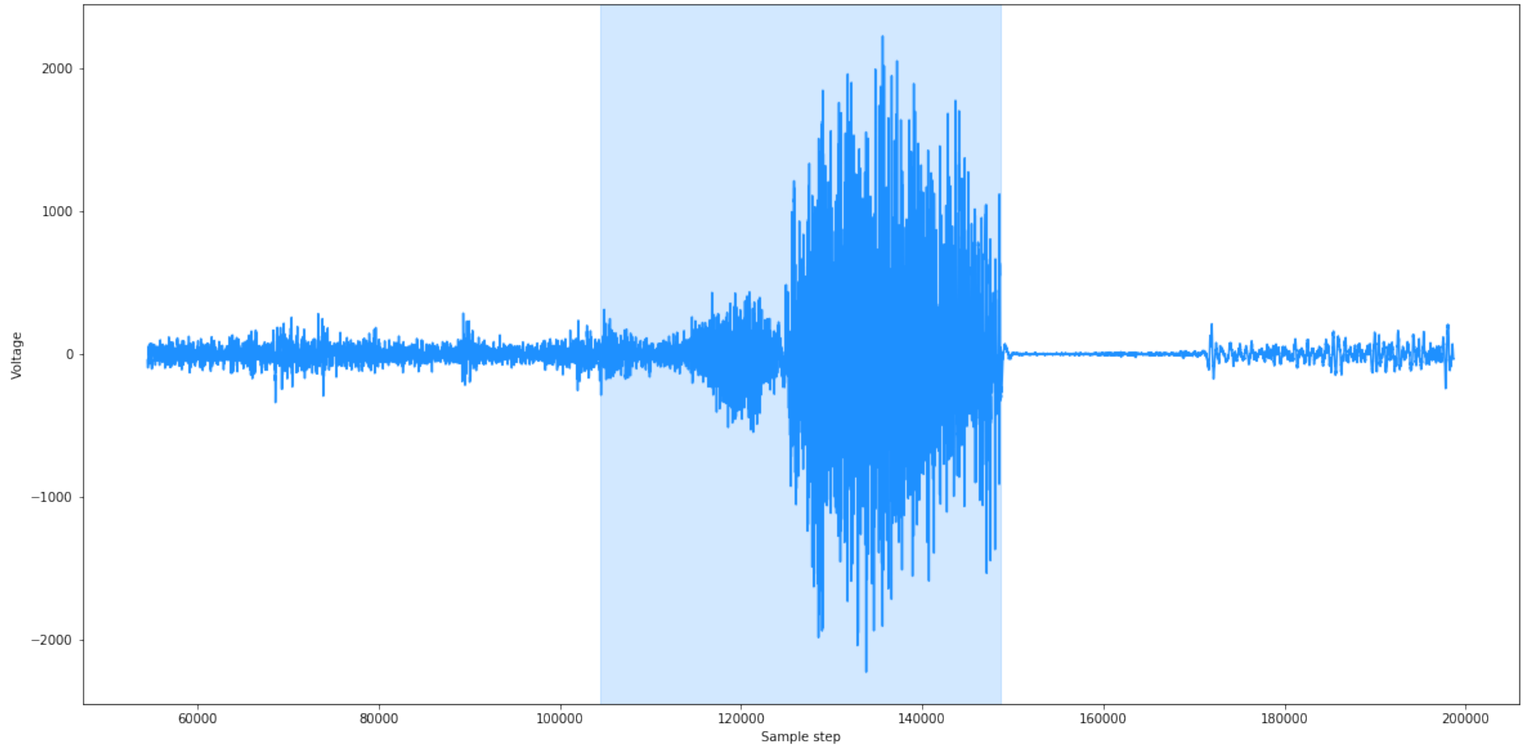
EMRICK SINITAMBIRIVOUTIN

EPILEPTIC SEIZURE DETECTION USING MACHINE LEARNING

Supervisor: Reza Ranjandish

EPILEPSY

- The disease is characterized by a recurrence of a brief abnormal and uncontrollable electrical discharge of the brain (Seizure)



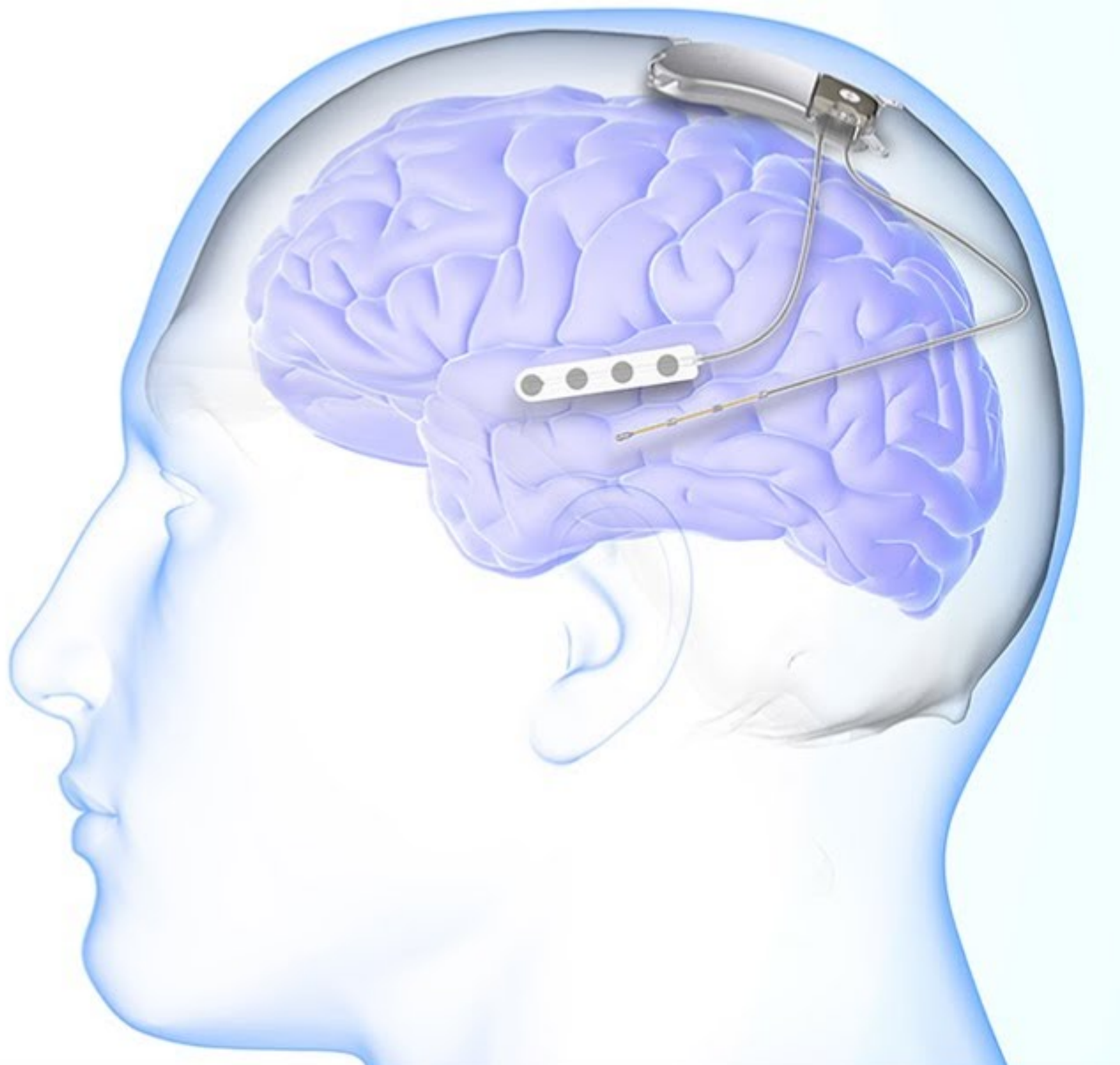
- **50 million** people world- wide have epilepsy
- **30%** are untreated or poorly treated

IMPLANTABLE DEVICES

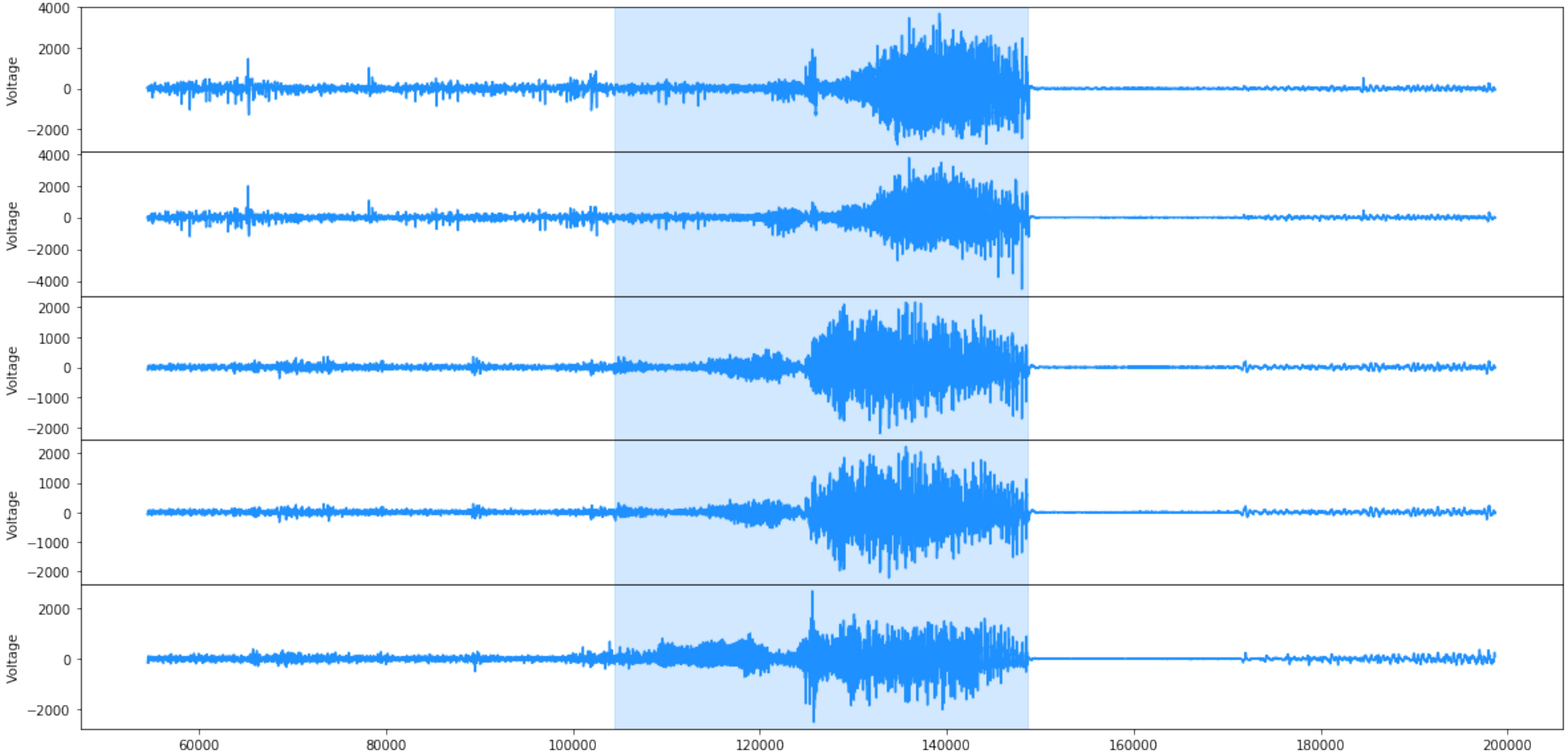
- Device that can monitor their brain activity and generate an electrical stimulation to stop their seizure when it is detected by the device.

CHALLENGES

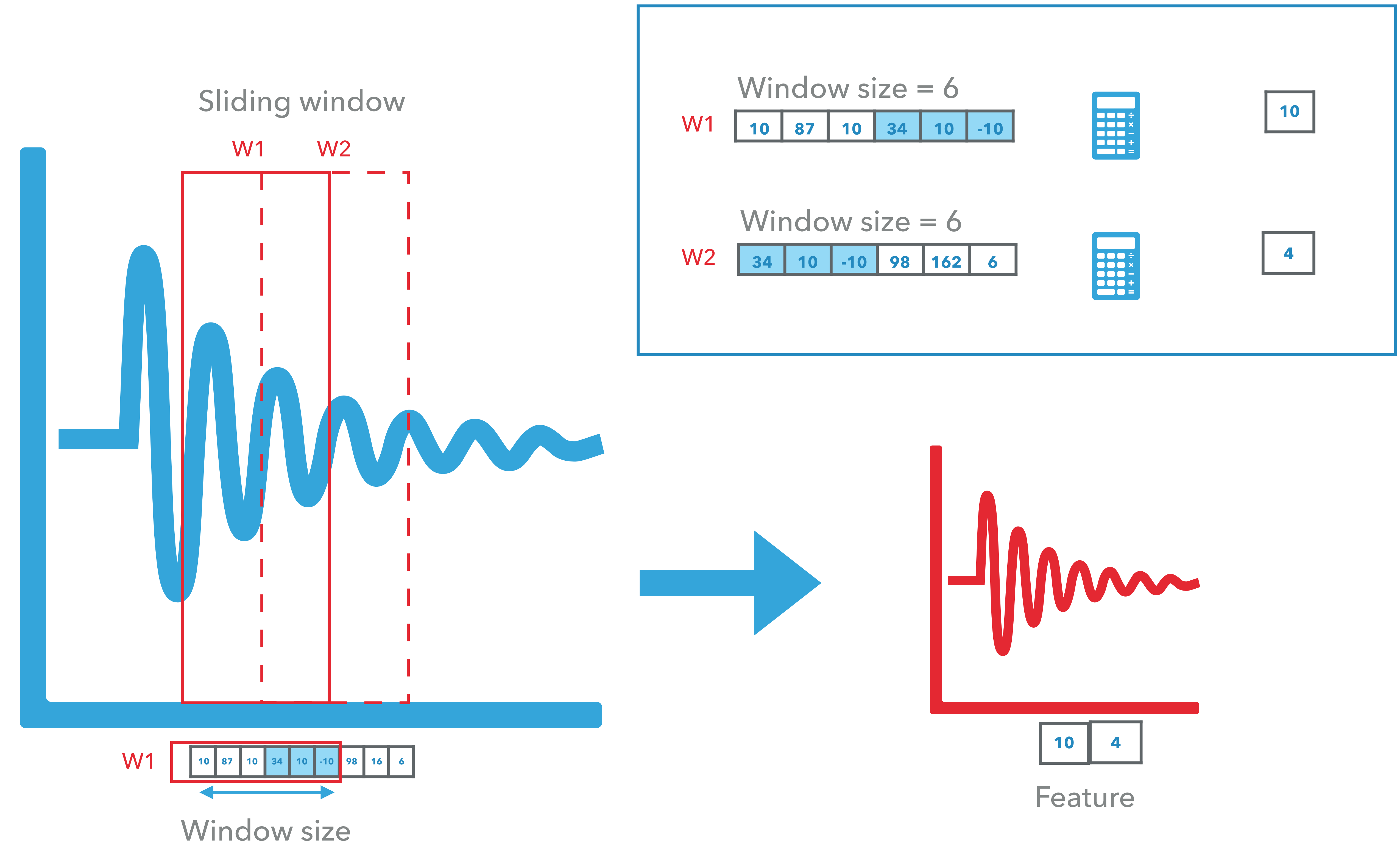
- Low power consumption
- Real time decision
- High accuracy



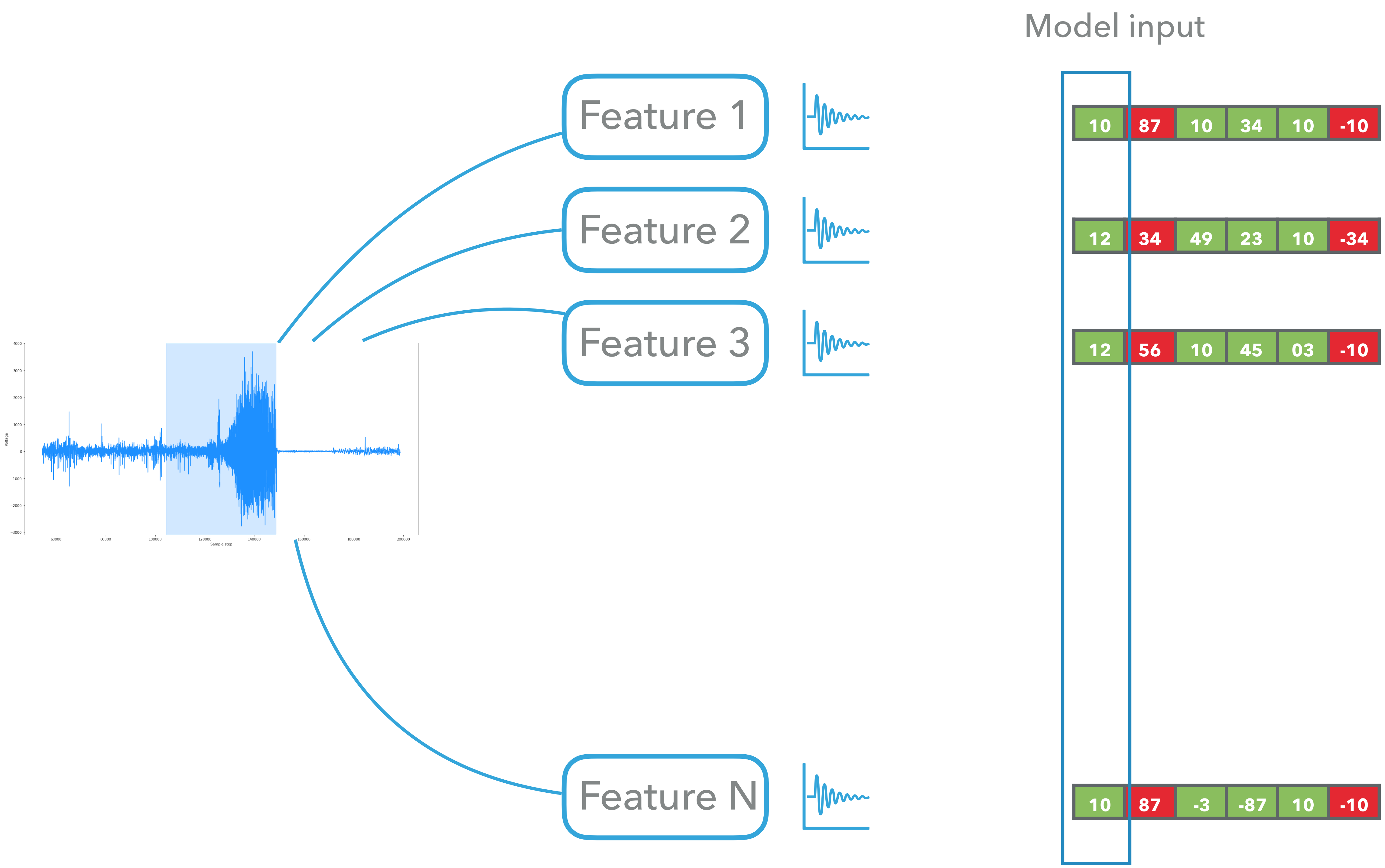
EXAMPLE OF IEEG RECORDING



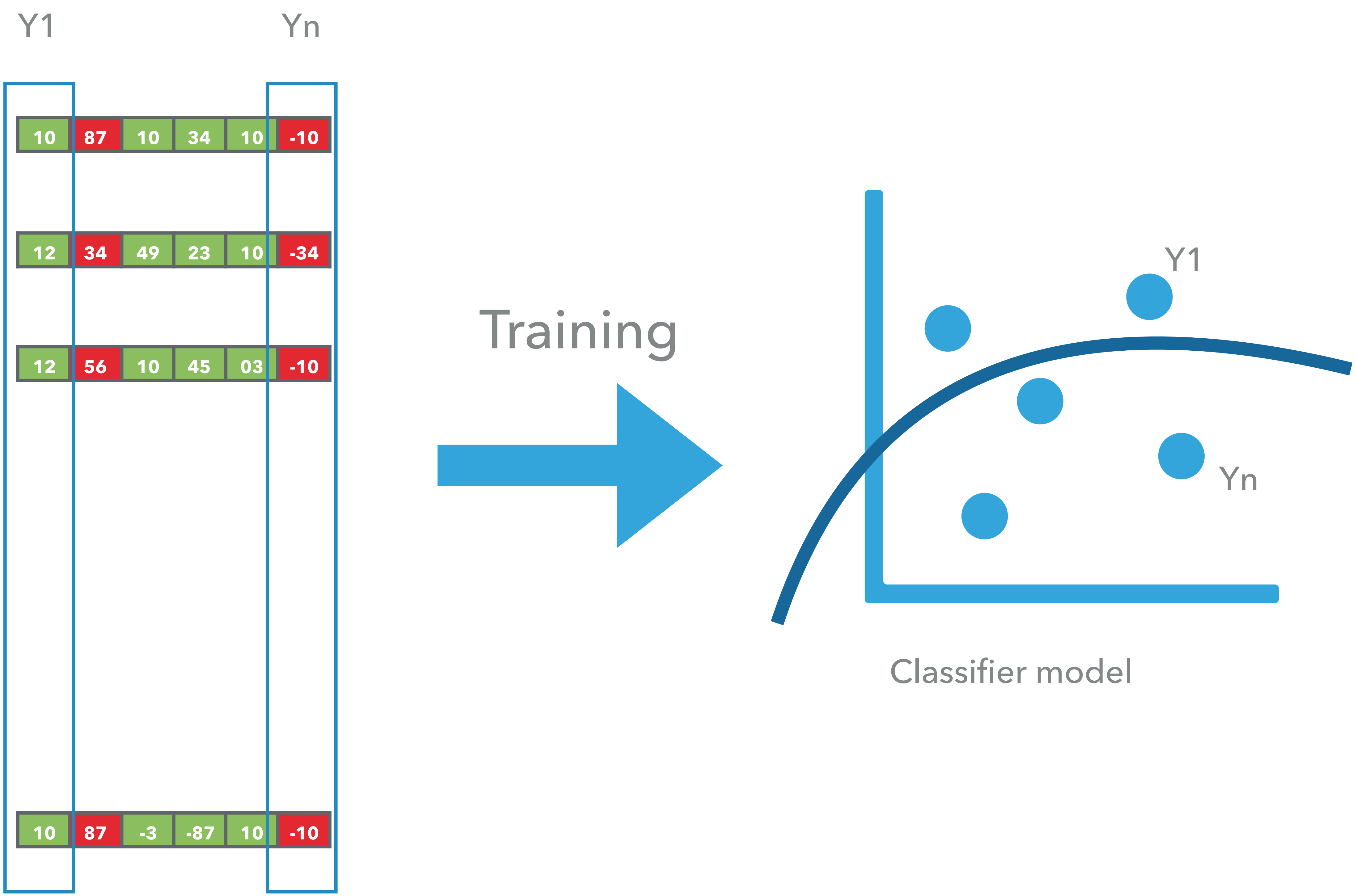
SIGNAL FEATURE



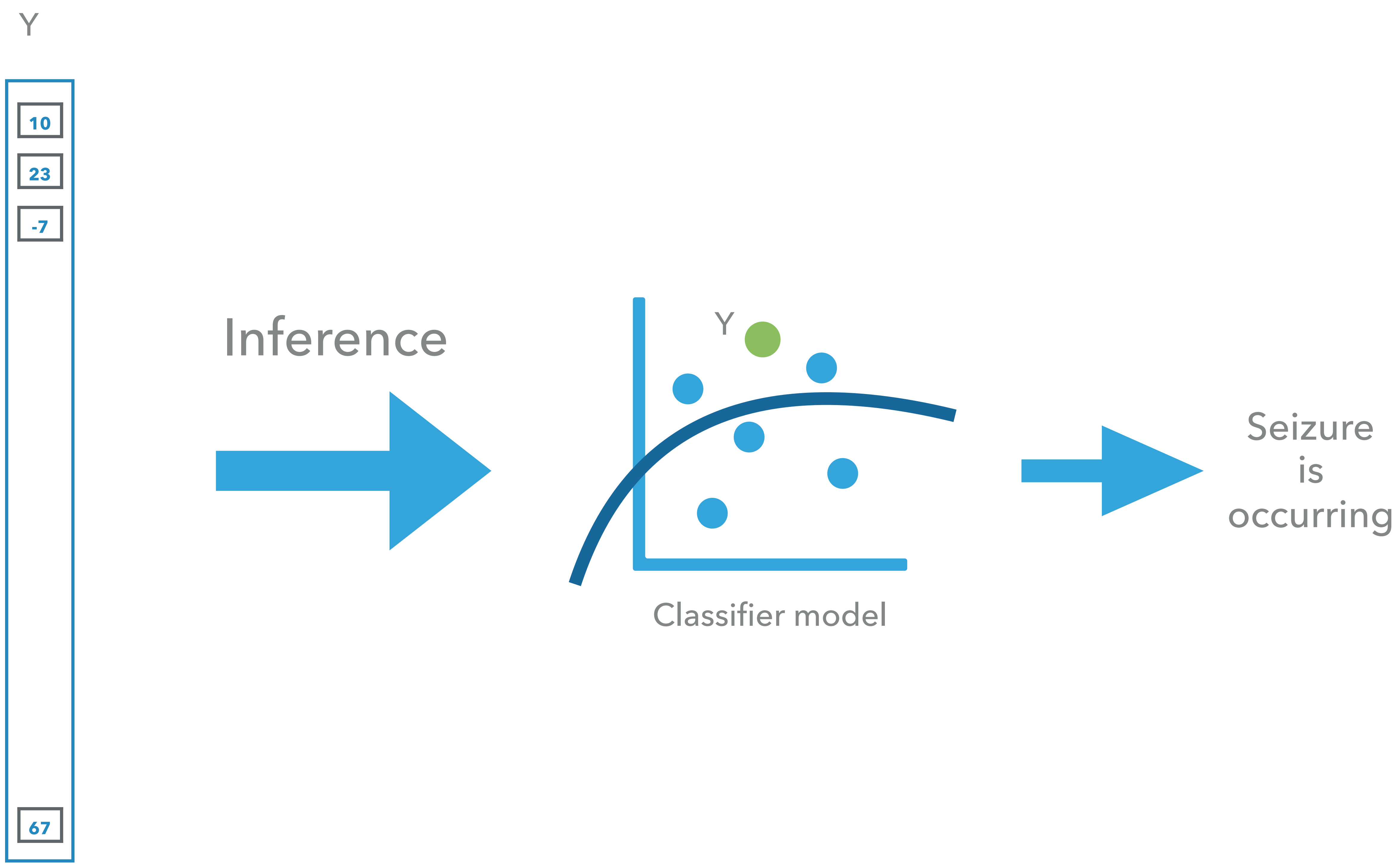
MACHINE LEARNING



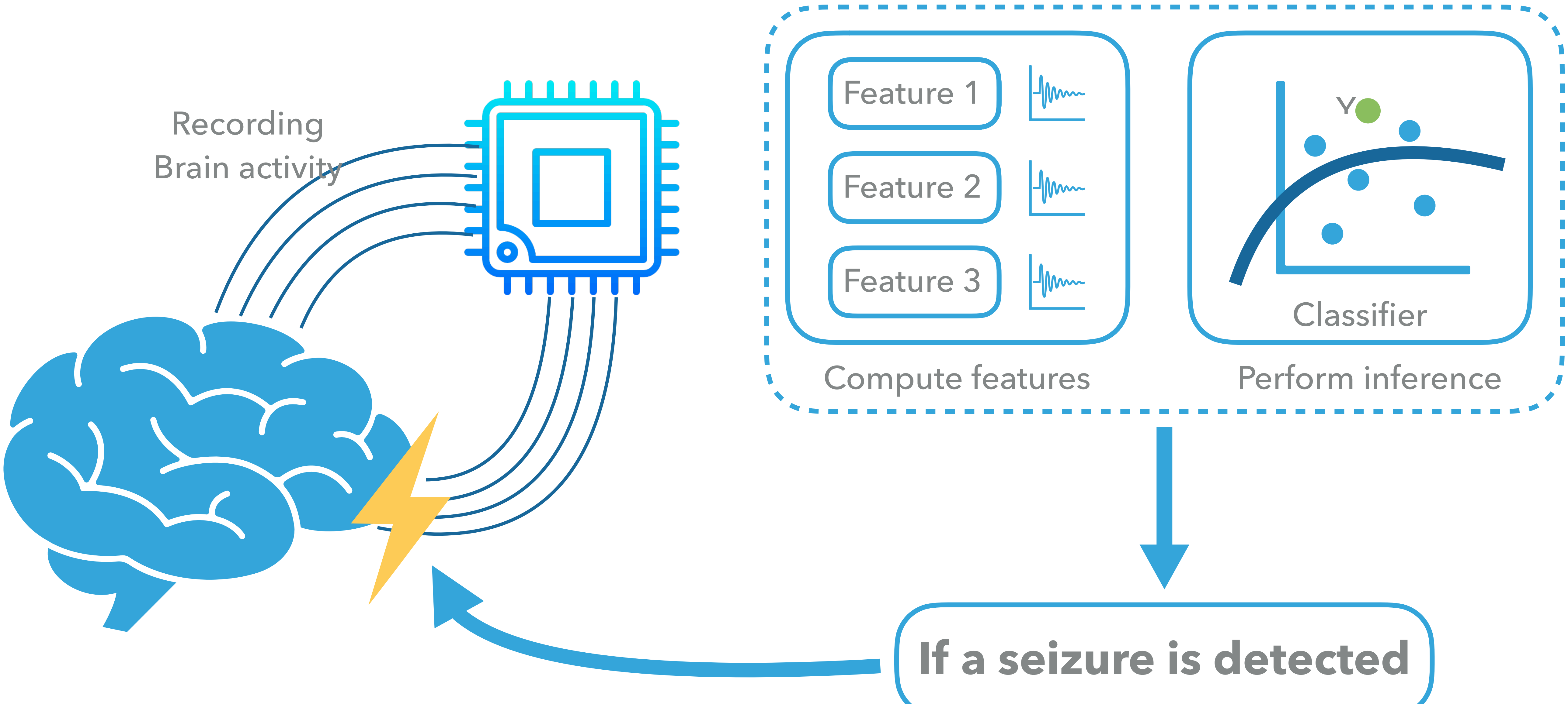
MACHINE LEARNING



MACHINE LEARNING



THE FINAL GOAL



TIME LINE

- **Why do we need specific features for a patient**
  - Heterogeneity between patient data
  - Seizures between patient can differ a lot
  - Why do we need features to train a classifier
- **How do we choose the right feature**
  - The metrics that we want to use (Precision, specificity, FA)
  - The scoring method that I propose (why this method, how it meets our objectives)
  - The features that I've tried and how do we calculate them
- **Results**
  - Score results obtained with the method
  - Comparison between different patients

WHY DO WE NEED
SPECIFIC FEATURES FOR A PATIENT ?

1. PATIENTS HETEROGENEITY

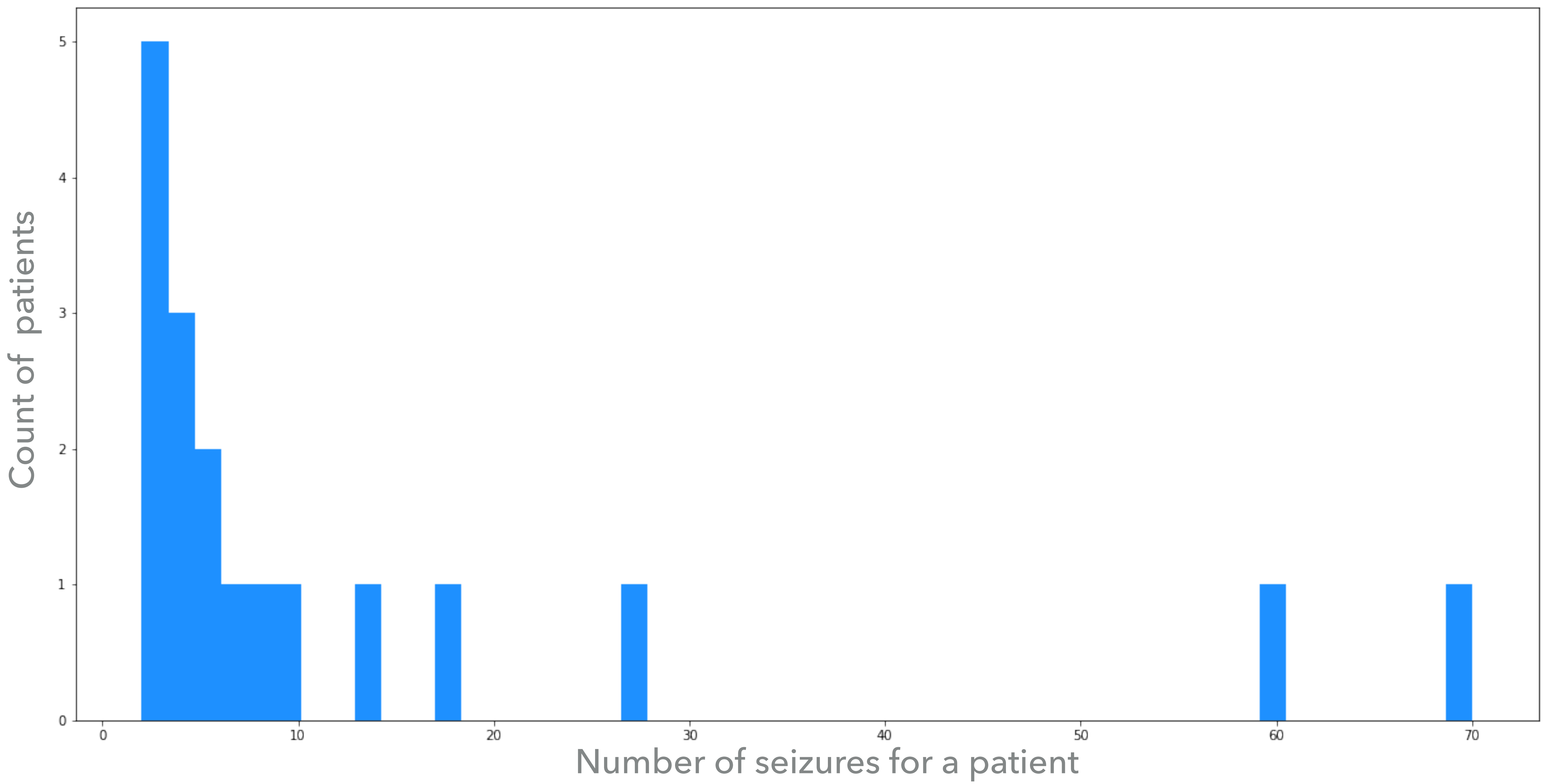
SWEC-ETHZ IEEG DATABASE

- **Long-term Dataset**: 2656 hours of anonymized and continuous intracranial electroencephalography (iEEG) of 18 patients with pharmaco-resistant epilepsies.
- **Short-term Dataset**: 100 anonymized intracranially recorded electroencephalographic (iEEG) datasets of 16 patients with pharmaco-resistant epilepsy.
- All the iEEG recordings were visually inspected by an EEG board-certified and experienced epileptologist (K.S.) for identification of seizures.

SEIZURE FREQUENCY

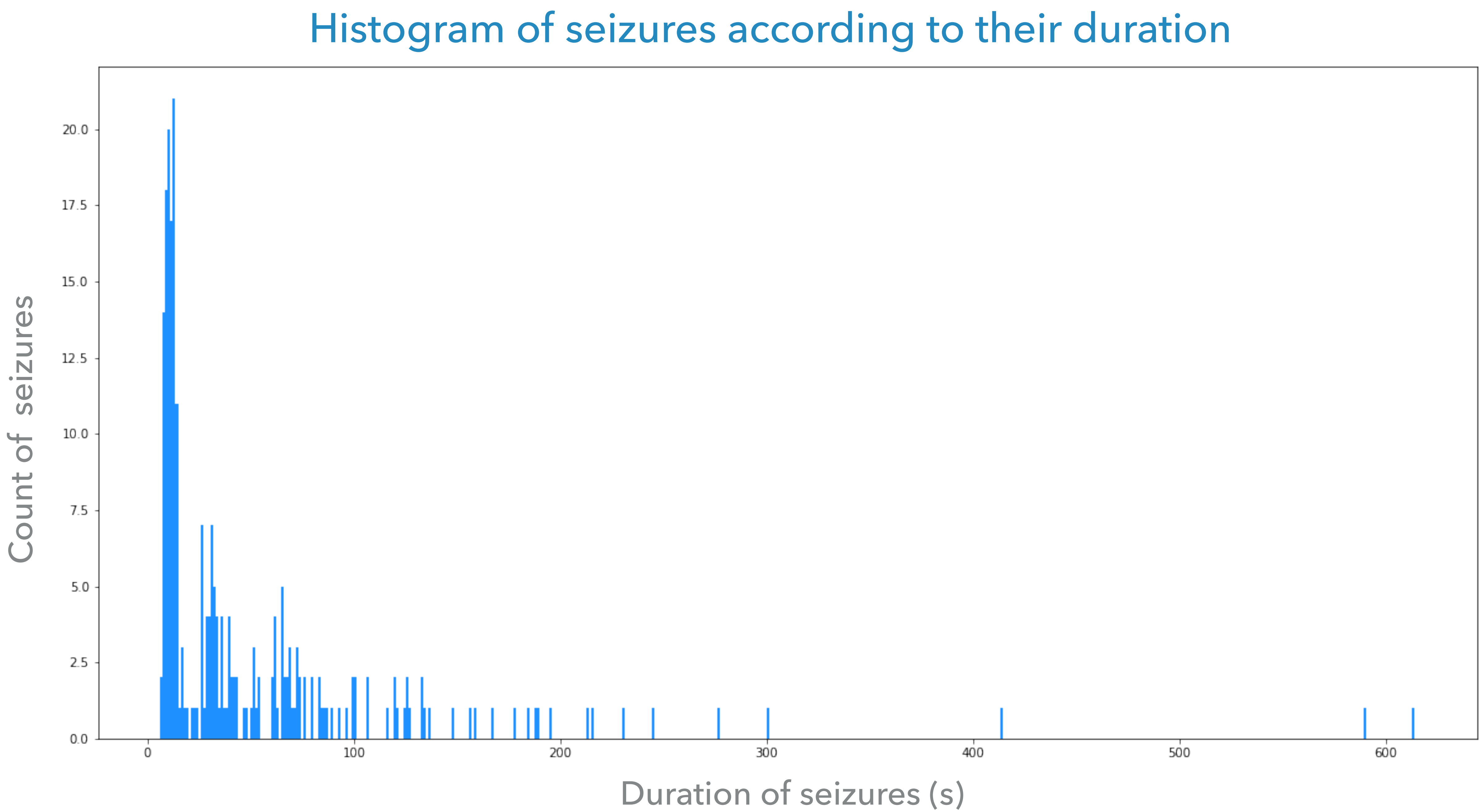
- Some patients have much more seizure during a period of time than other patient.

Histogram of patients according to their number of seizures



SEIZURE DURATION

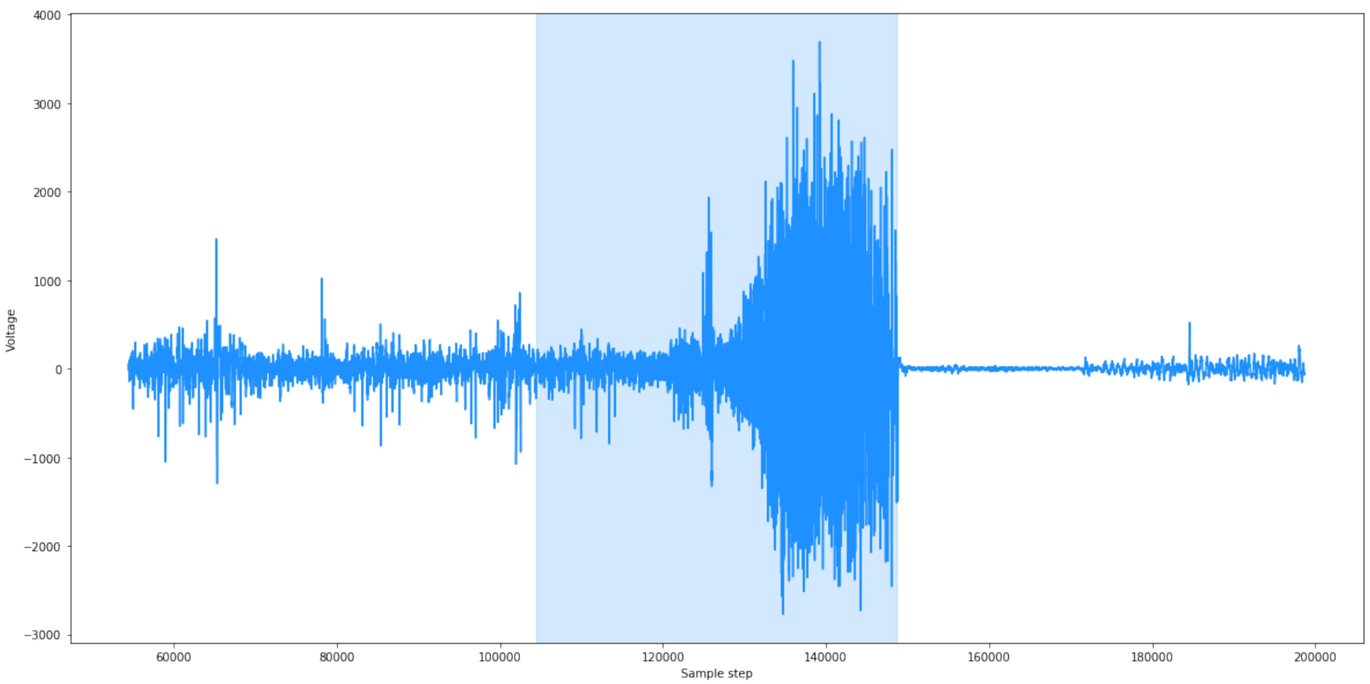
- Seizure duration can vary a lot.



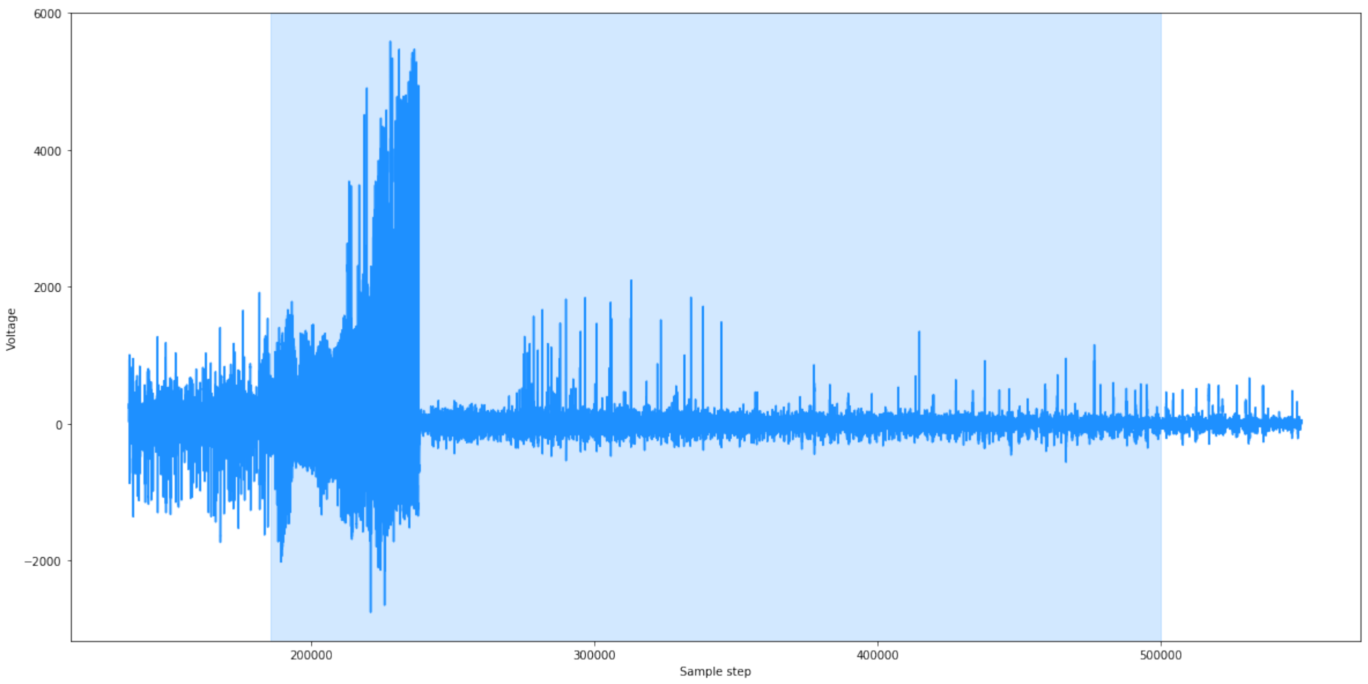
PATIENT HETEROGENEITY

SEIZURE SIGNALS

Patient 1 (First seizure)



Patient 2 (First seizure)



SEIZURE DURATIONS STATICTICS

- Statistics show that some patients have a high variability in term of seizure duration.
- Some patients have much more seizures than others

Low variance in term of duration

High variance in term of duration

Patient	number of seizures	mean duration	std duration	min duration	max duration
1	2	601.787	16.9381	589.81	613.764
2	2	88.0625	2.55547	86.2555	89.8695
3	4	64.6619	4.14865	60.5449	68.234
4	14	41.9404	13.779	7.77257	68.6968
5	4	16.6878	0.512328	15.9232	17.013
6	8	45.8905	32.8707	29.3444	126.882
7	4	69.5688	38.6222	14.1287	98.8148
8	70	21.9668	53.88	6.22336	413.385
9	27	42.377	35.5274	18.7427	148.283
10	17	70.8471	10.7102	61.2513	106.262
11	2	91.5471	11.9259	83.1142	99.98
12	9	146.461	33.0413	106.836	194.754
13	7	103.004	60.9422	40.1964	188.44
14	60	25.8067	24.3826	6.37323	100.775
15	2	94.5809	35.5882	69.4163	119.746
16	5	190.445	50.6856	120.293	245.196
17	2	97.9362	1.28925	97.0246	98.8479
18	5	199.132	100.565	71.4387	300.651

HOW DO WE CHOOSE THE RIGHT FEATURE ?

2.FEATURE SELECTION AND SCORING

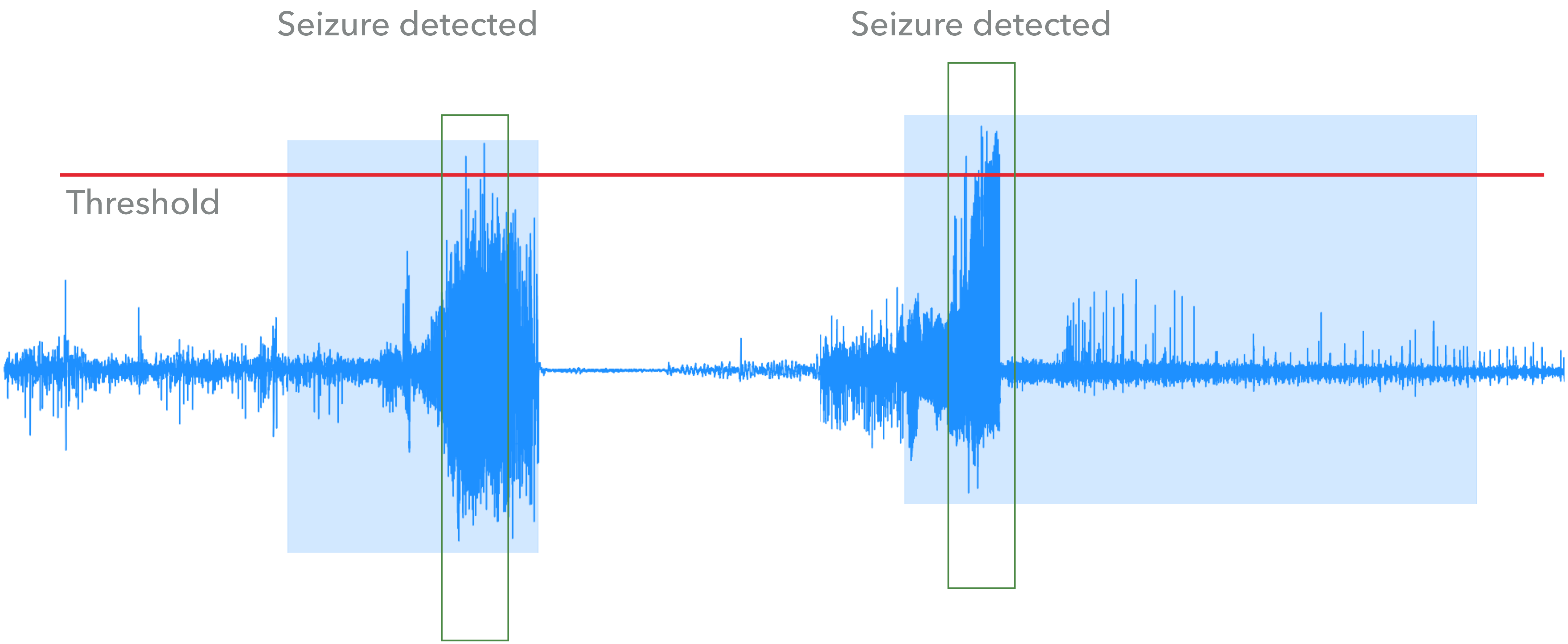
METRICS

- **Accuracy :** The number of detected seizure other all seizures
- **False alarms :** The number of seizure detection that didn't occurred during a true seizure
- **Delay :** The time between the real start of a seizure and the moment of the first valid detection

METRICS: ACCURACY

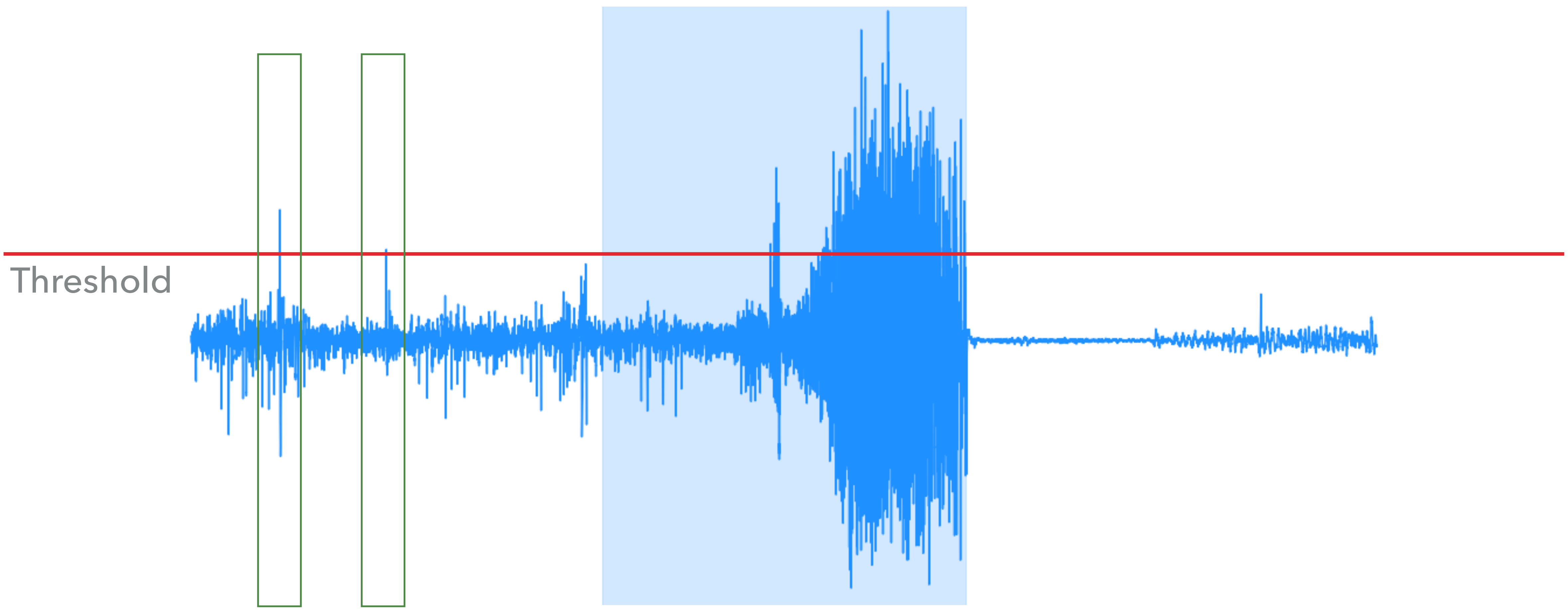
ACCURACY: 50%

METRICS: ACCURACY



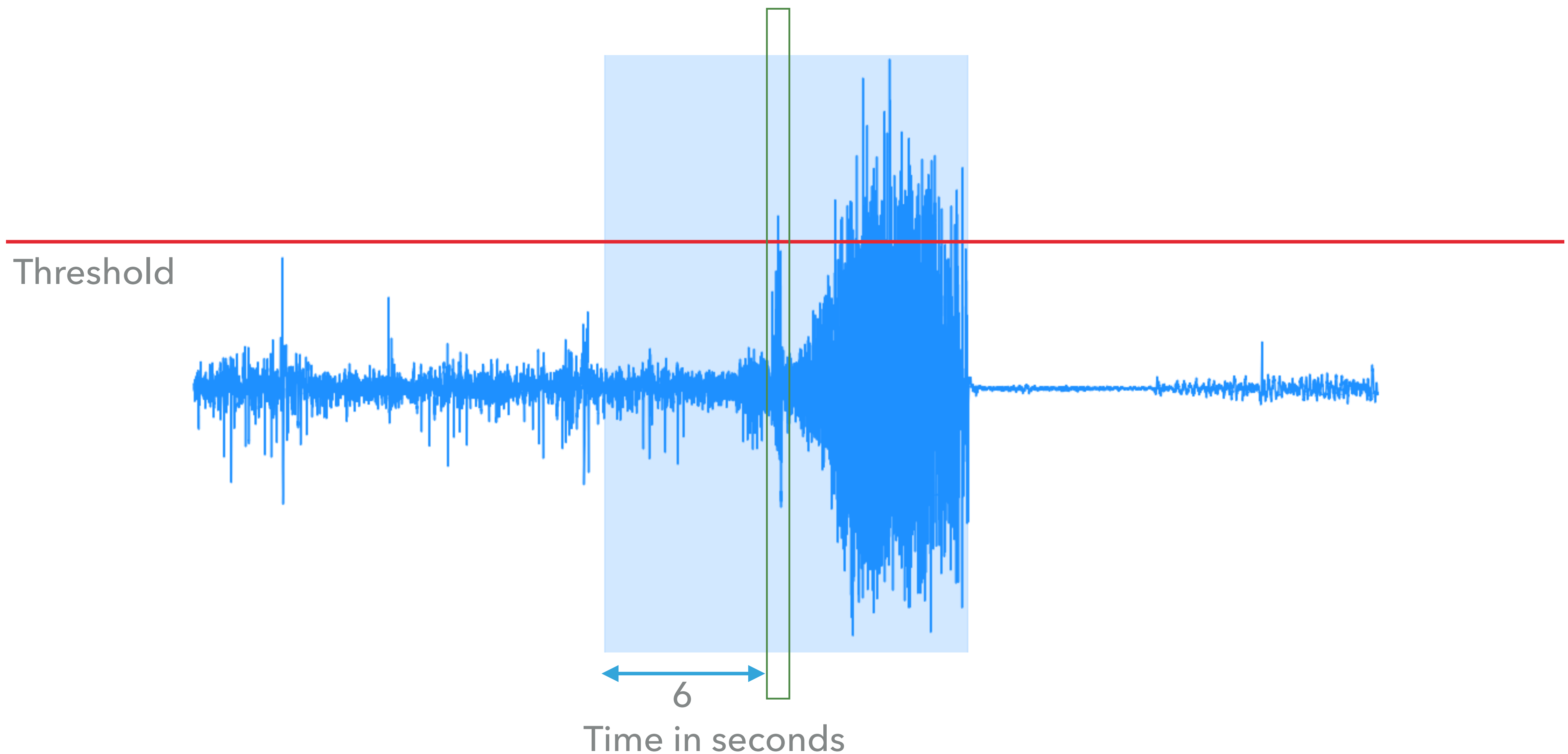
ACCURACY: 100%

METRICS: FALSE ALARM



FALSE ALARM: 2

METRICS: DELAY

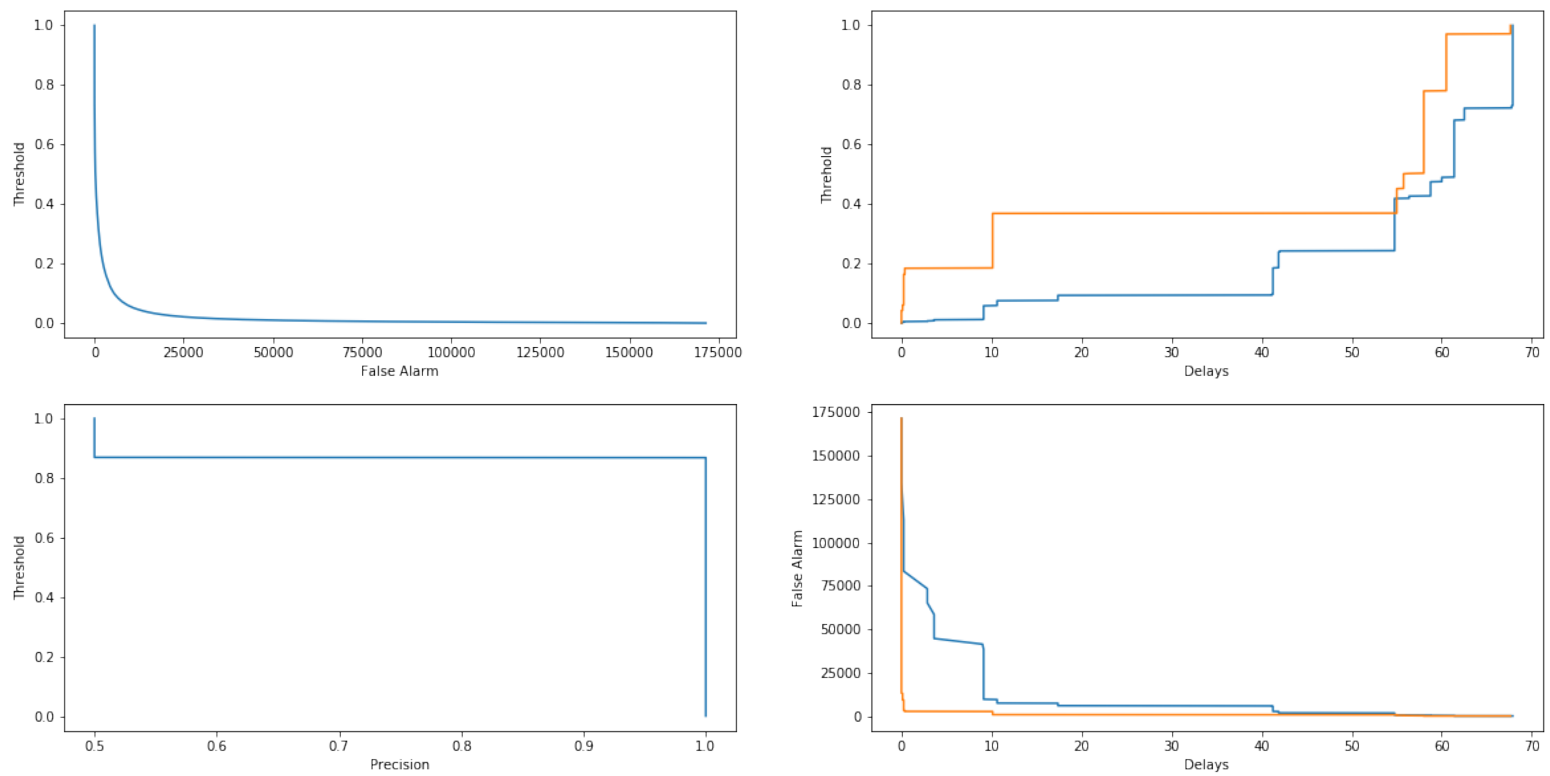


DELAY: 6S

GOALS OF THE SCORING

Goal 1 (for each seizure)

- Minimize False Alarms
- Minimize delays (lower than 10 seconds)
- Accuracy of 1

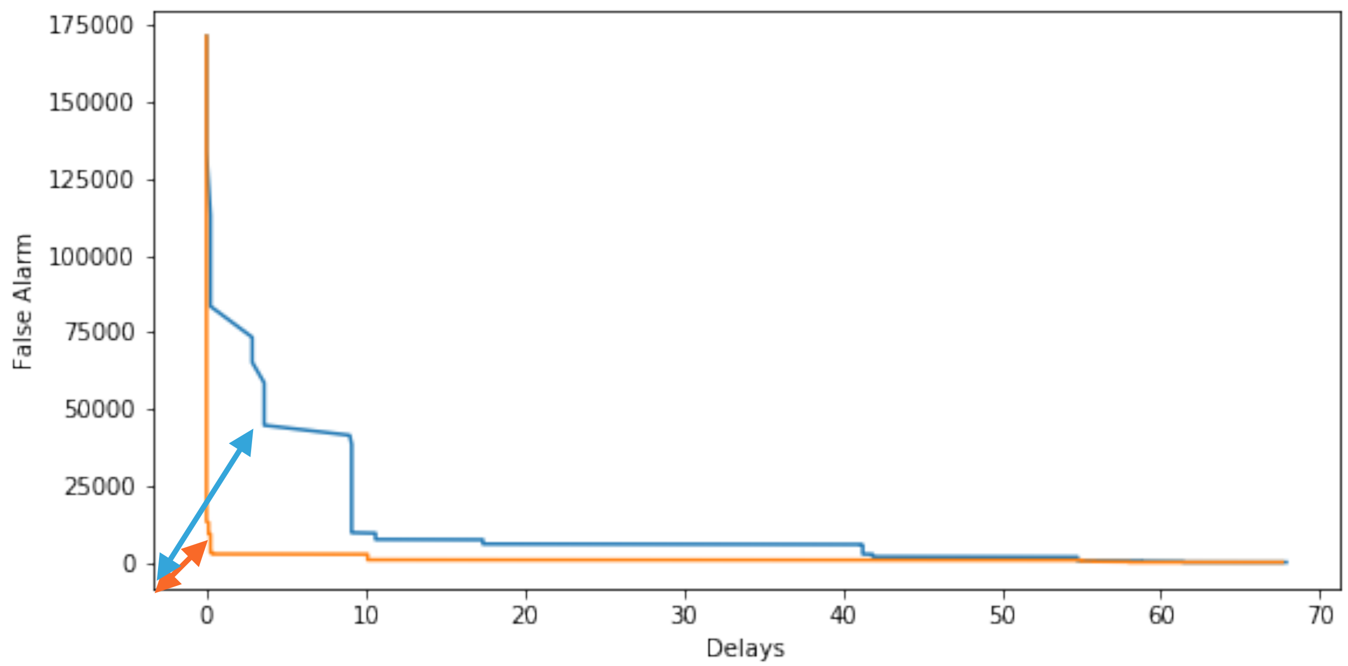


Goal 2 (for all patient seizure)

- Have a high average score
- Have low variation of the threshold value

SOLUTION FOR GOAL 1 (SCORE 1)

The higher the score S1 is, the best FA and Delay combination that we found for the seizure



We compute the inverse of the norm 2 : $\|(x, y, z)\|^2 = \sqrt{x^2 + y^2 + z^2}$.

With $x = w_1 * FA$, $y = w_2 * D$, $z = w_3 * 1/P$

$$\frac{1}{\sqrt{(w_1 * FA)^2 + (w_2 * D)^2 + \frac{1}{(w_3 * P)^2} + \lambda}}$$

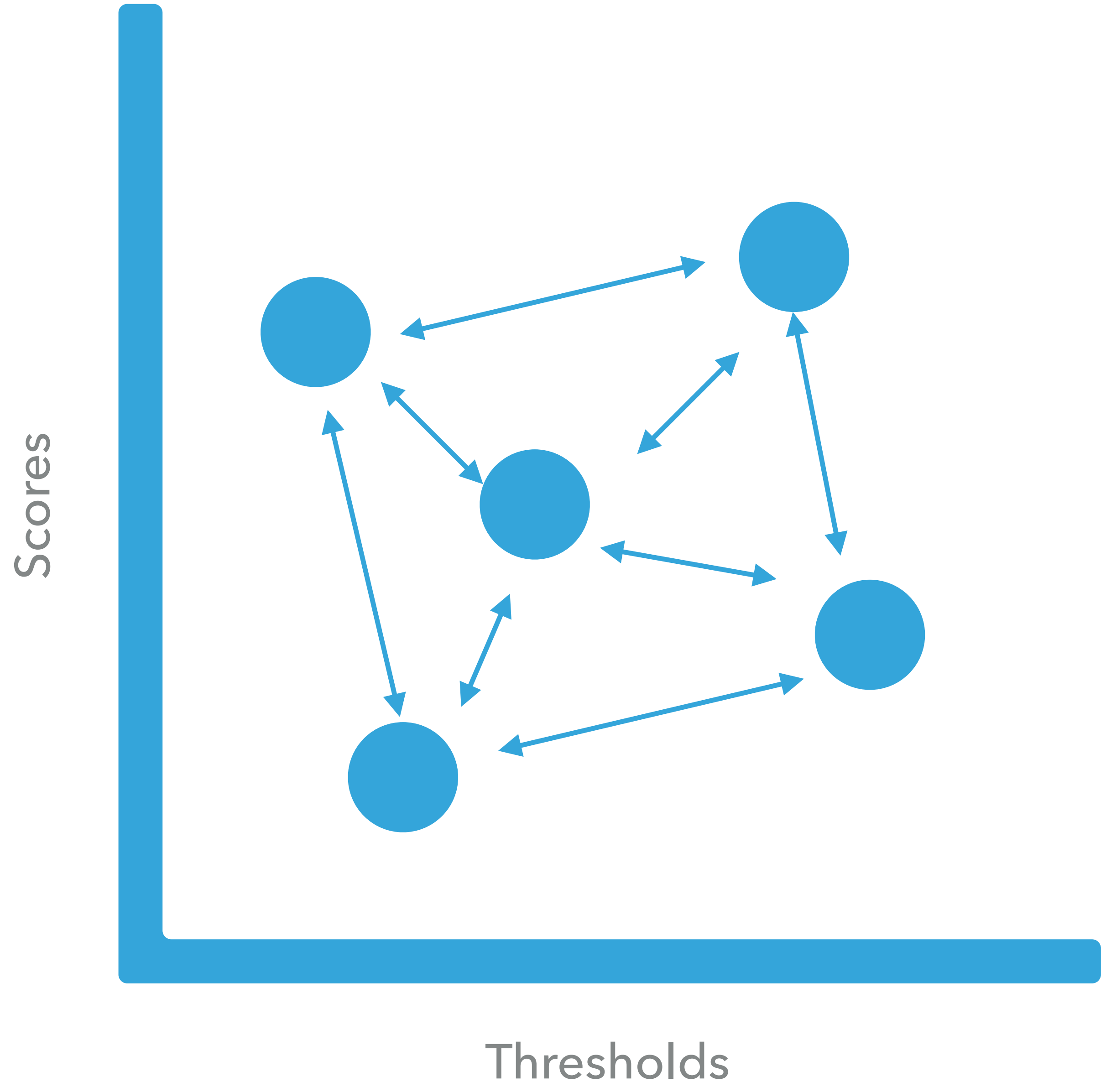
Remarks:

- λ is a small number avoiding division by zero
- We consider that each point in a 3-D coordinates point in the space of False Alarm, Delay and Precision for a given threshold value
- FA and D are normalised before the computation of the score
- We enforce the Delay to be inferior to D_{max}
- w_1, w_2, w_3 are wights that can be defined to give more importance of some metrics upon others

SOLUTION TO GOAL 2 (SCORE S2)

We want to minimize the distance between all the points.

Closer points means better generalization



FINAL SCORE

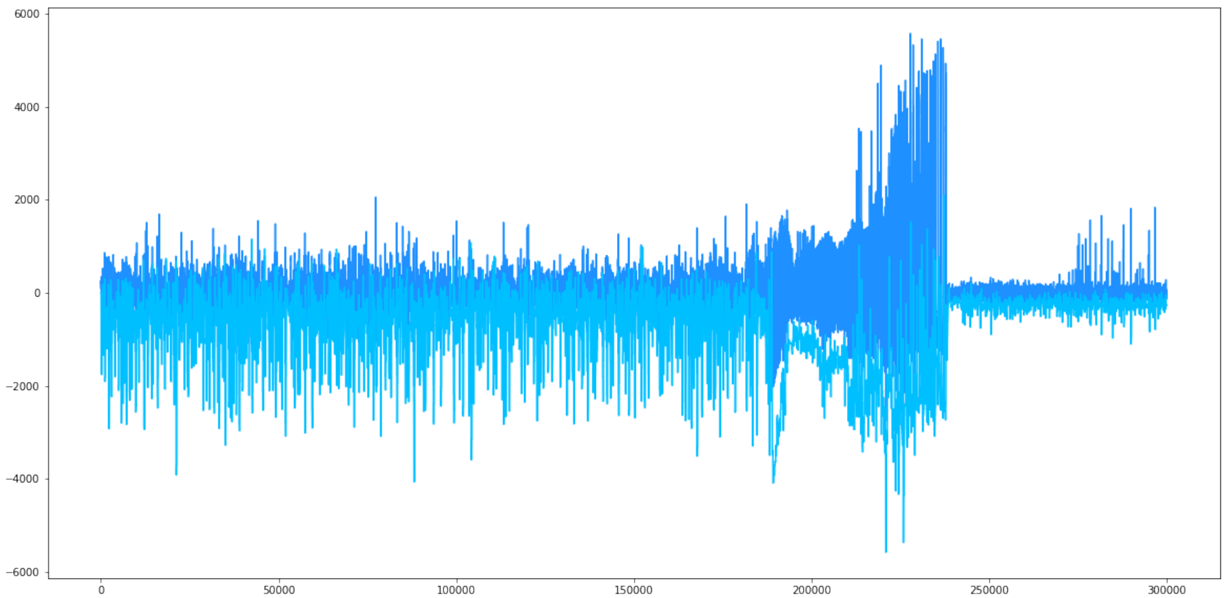
$$S = \frac{\sum_{k=0}^{n} S1_k}{n} \frac{1}{S2}$$

WHAT DO WE LEARN FROM THIS NEW SCORING METHOD ?

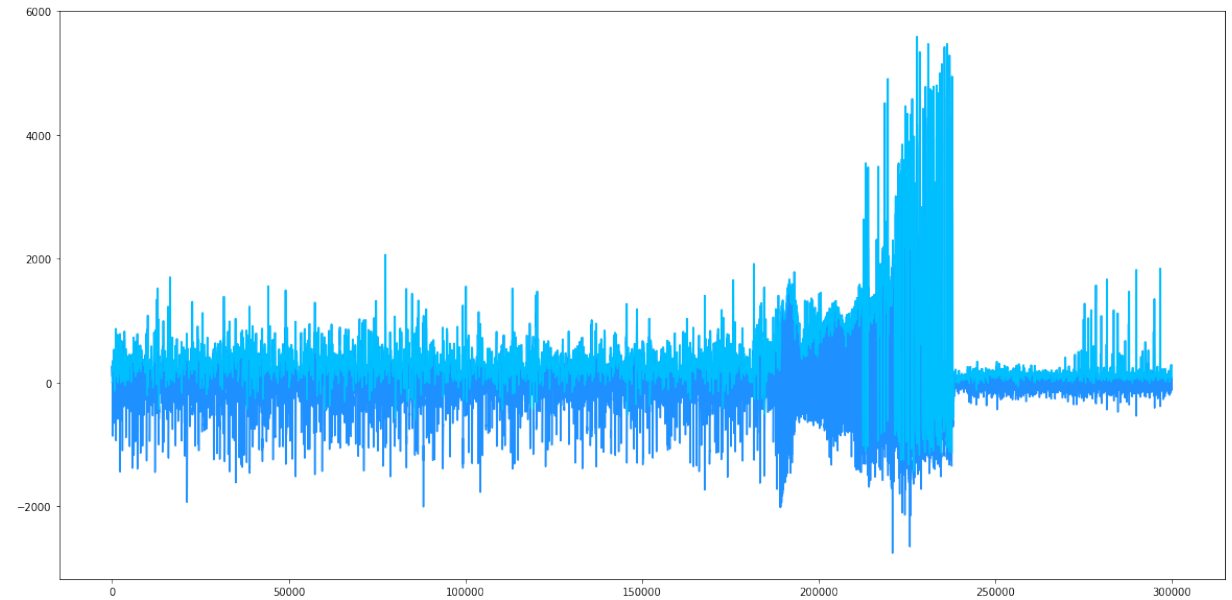
RESULTS

SIMPLE FEATURES

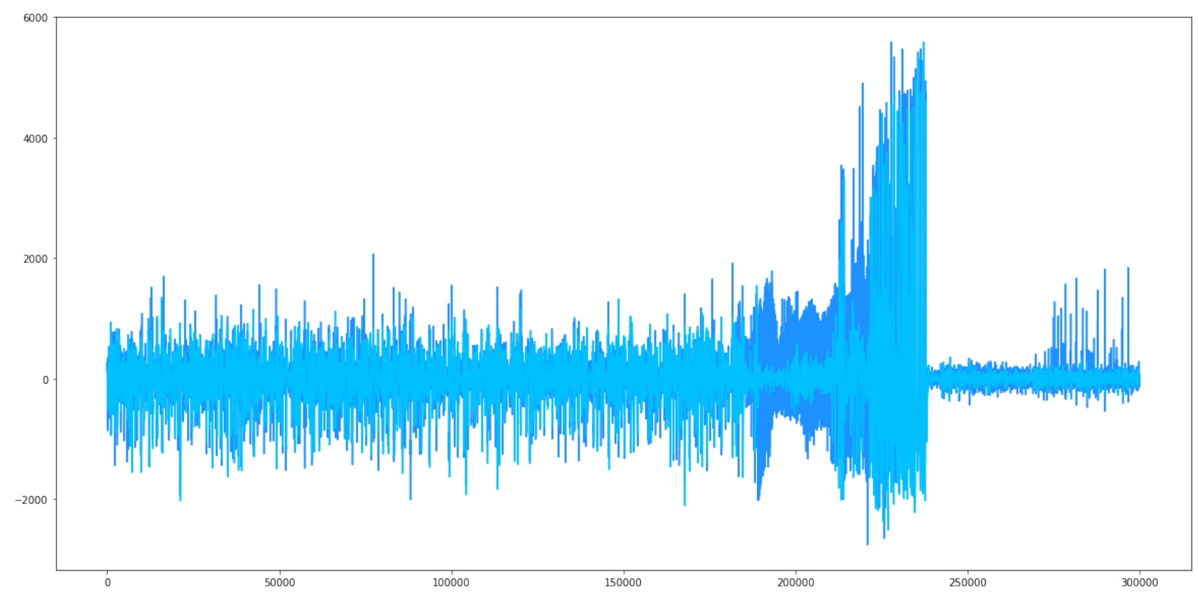
Minimum



Maximum

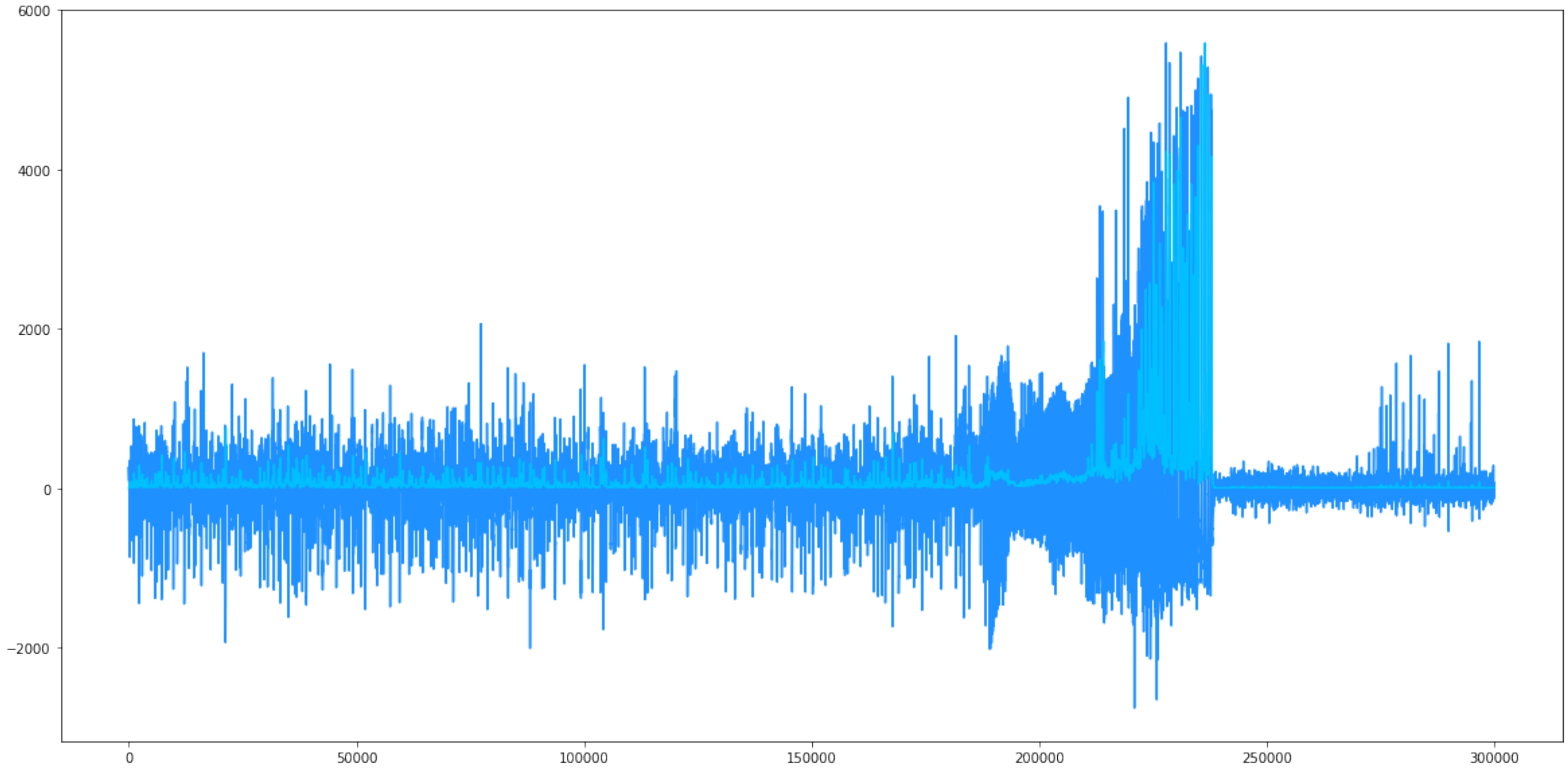


Moving AVG

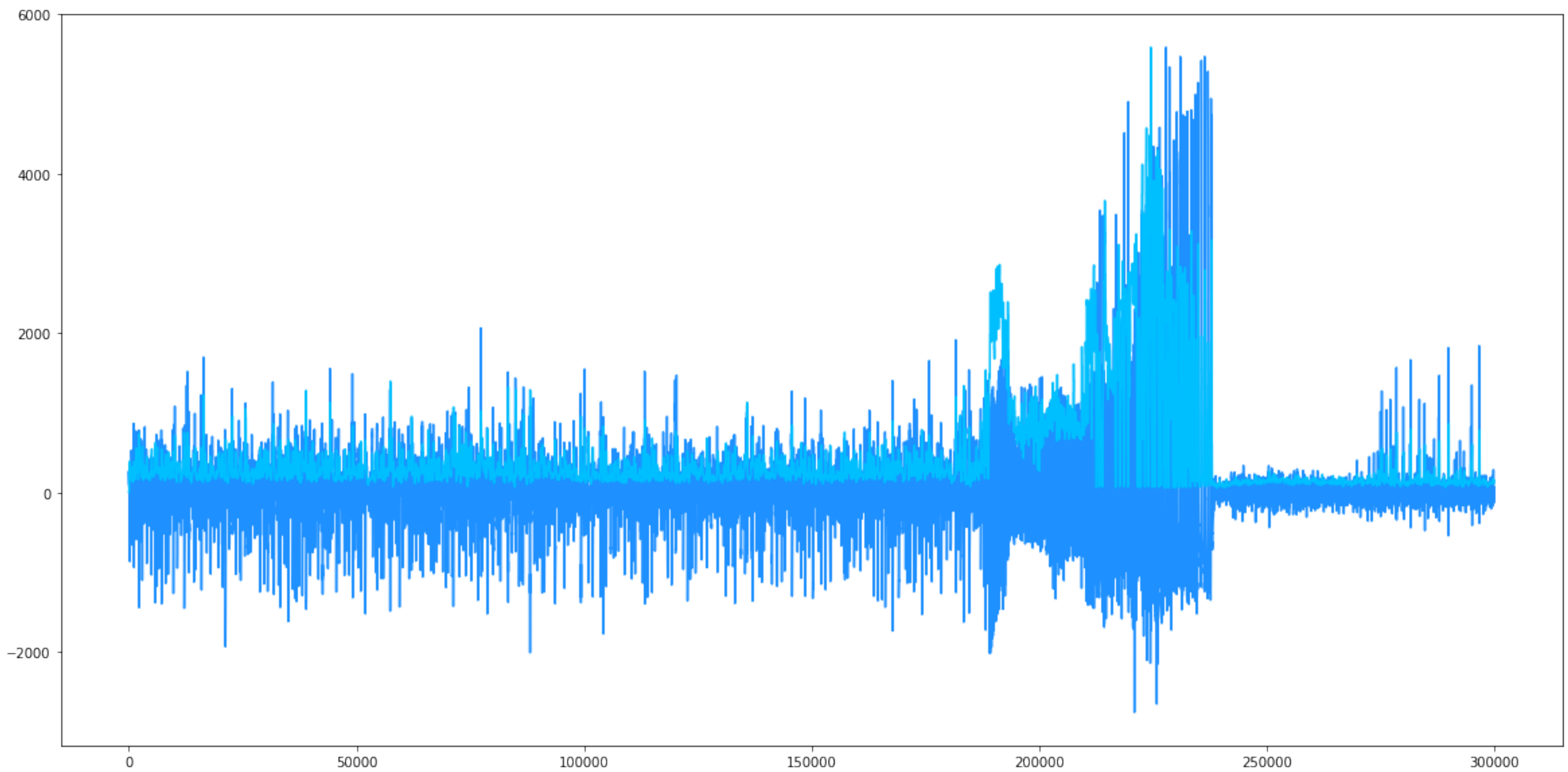


RESULTS

ENERGY



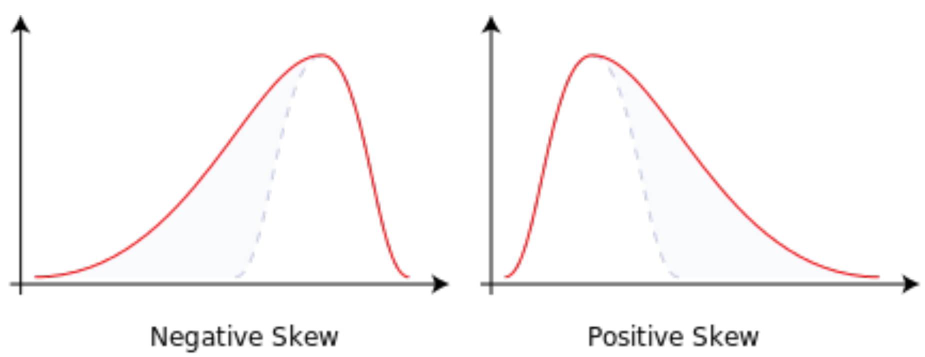
LINE LENGTH


6000
4000
2000
0
−2000
0
50000
100000
150000
200000
250000
300000

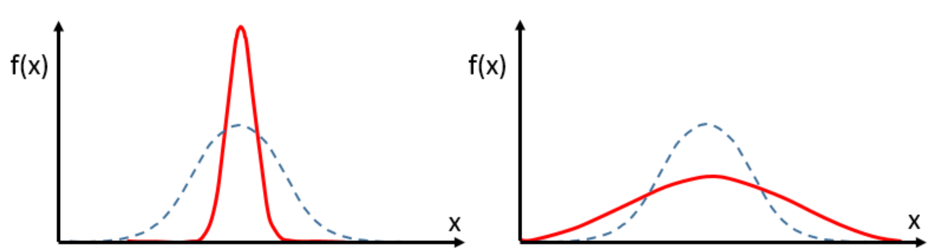
RESULTS

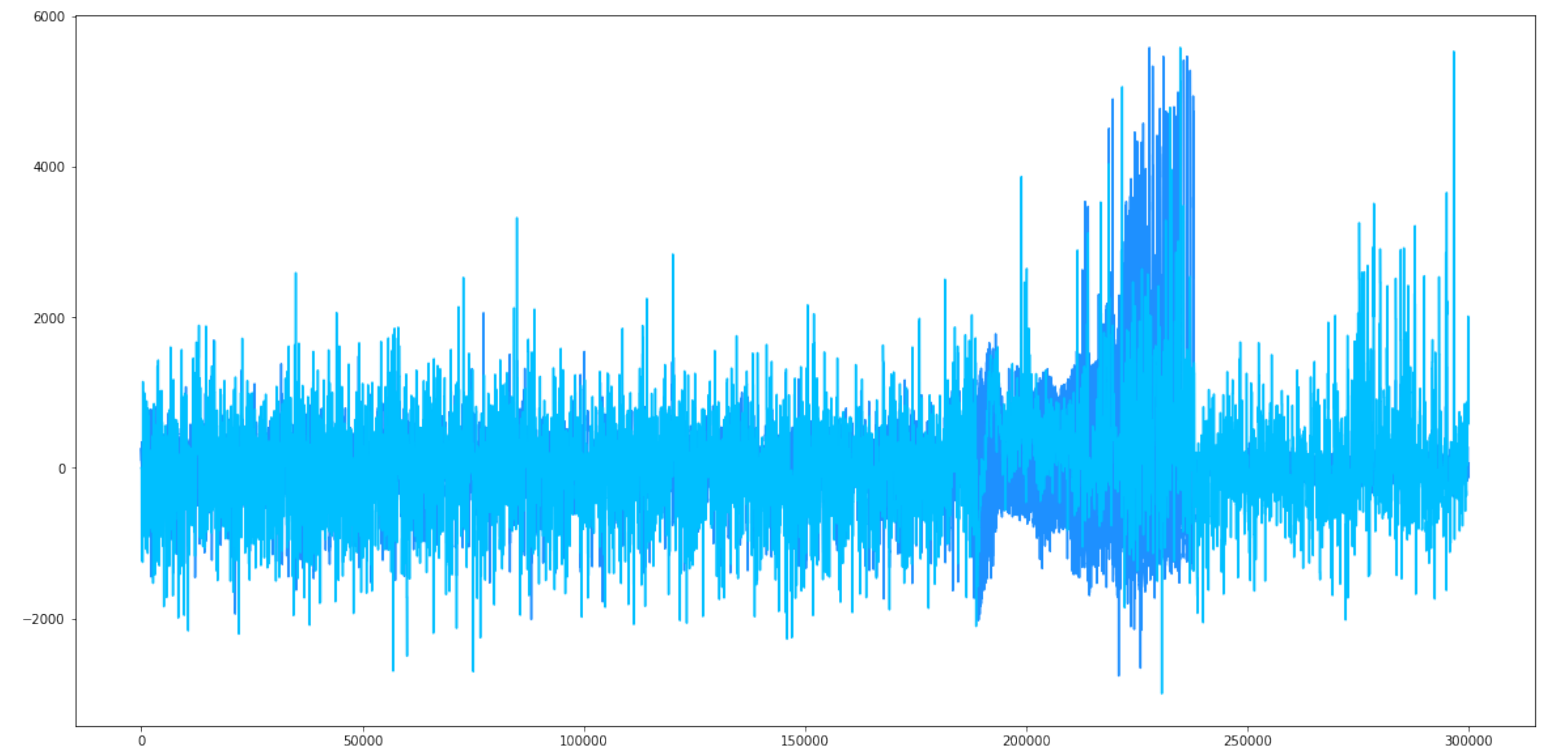
SKEWNESS AND KURTOSIS

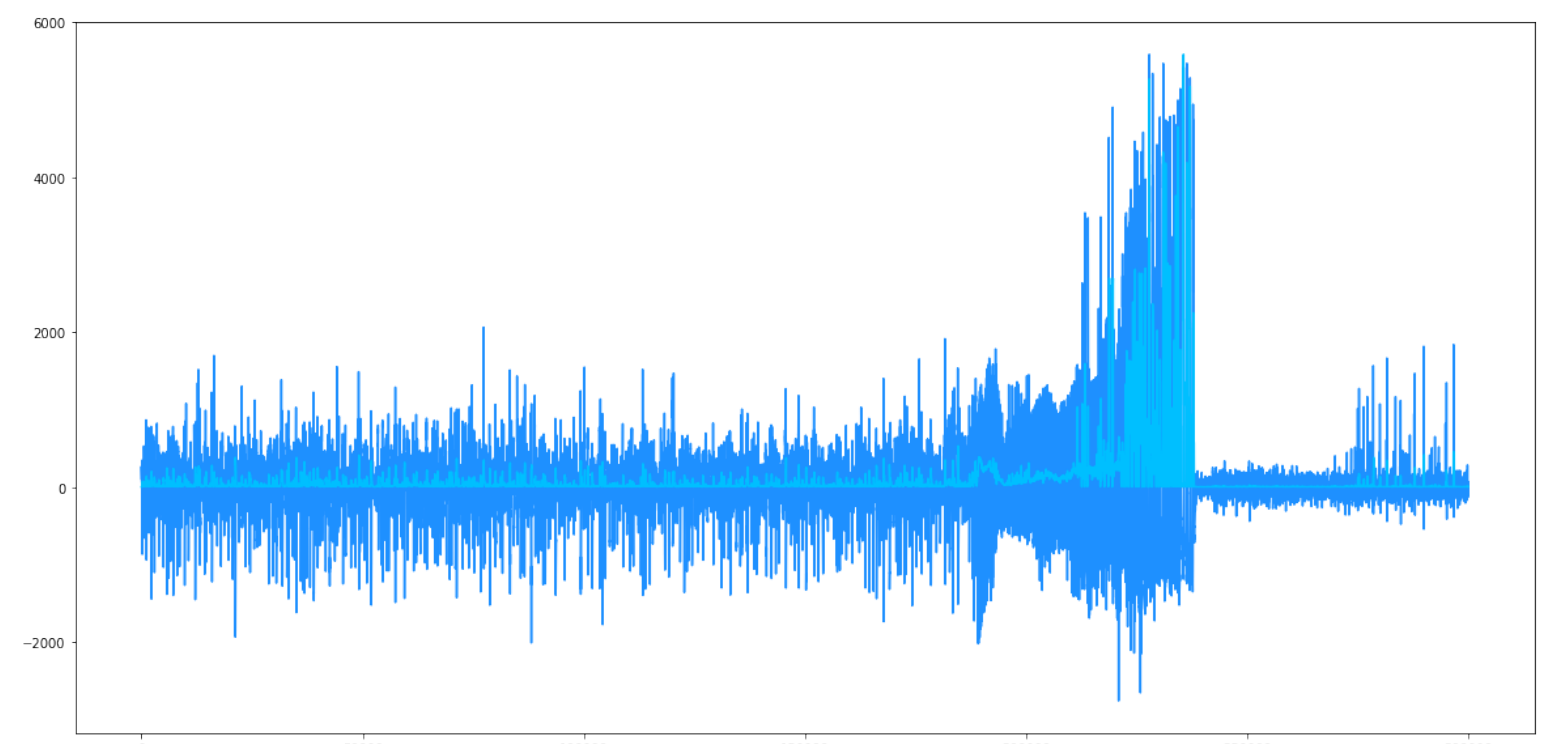
Skewness



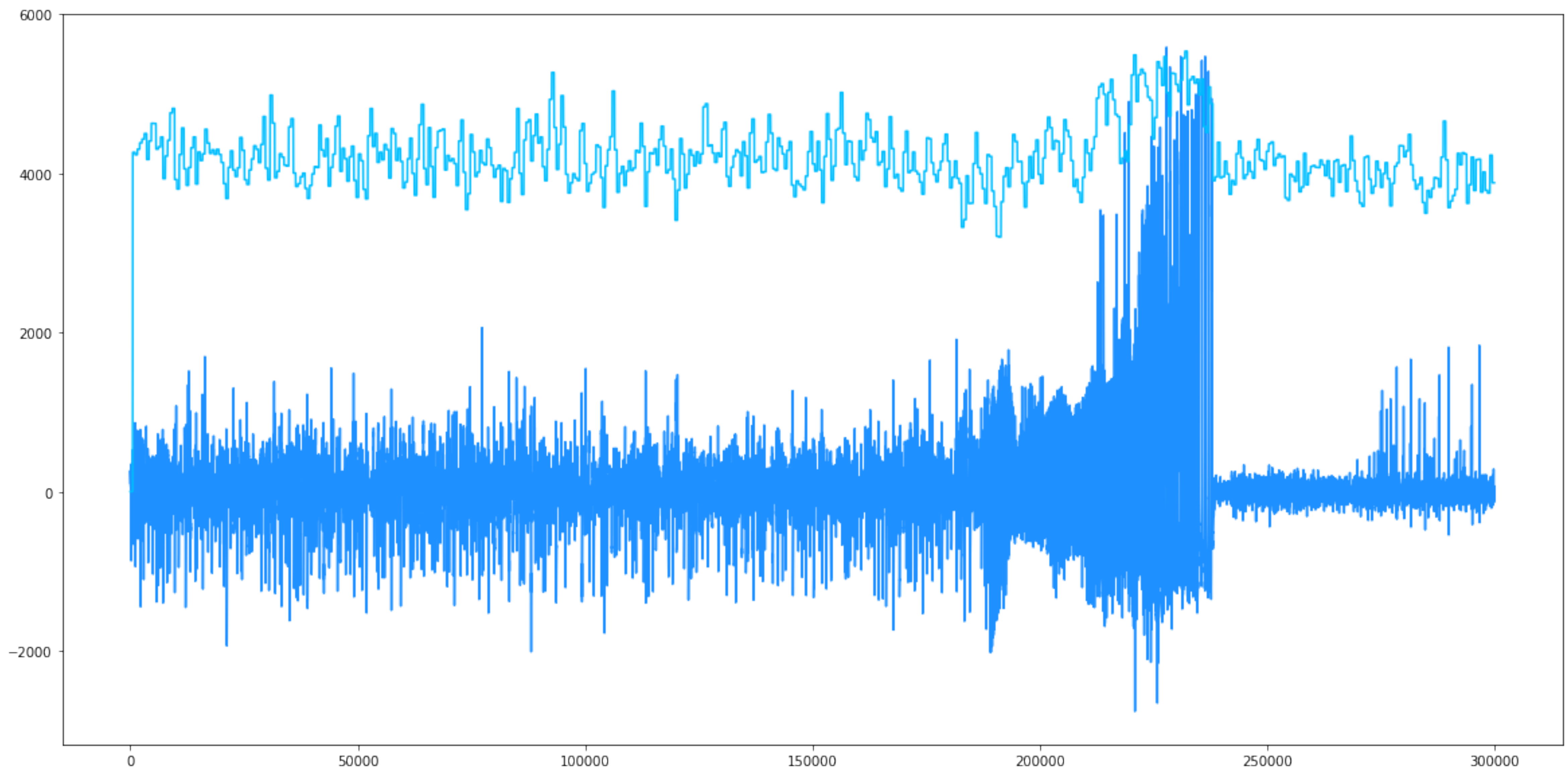
Kurtosis





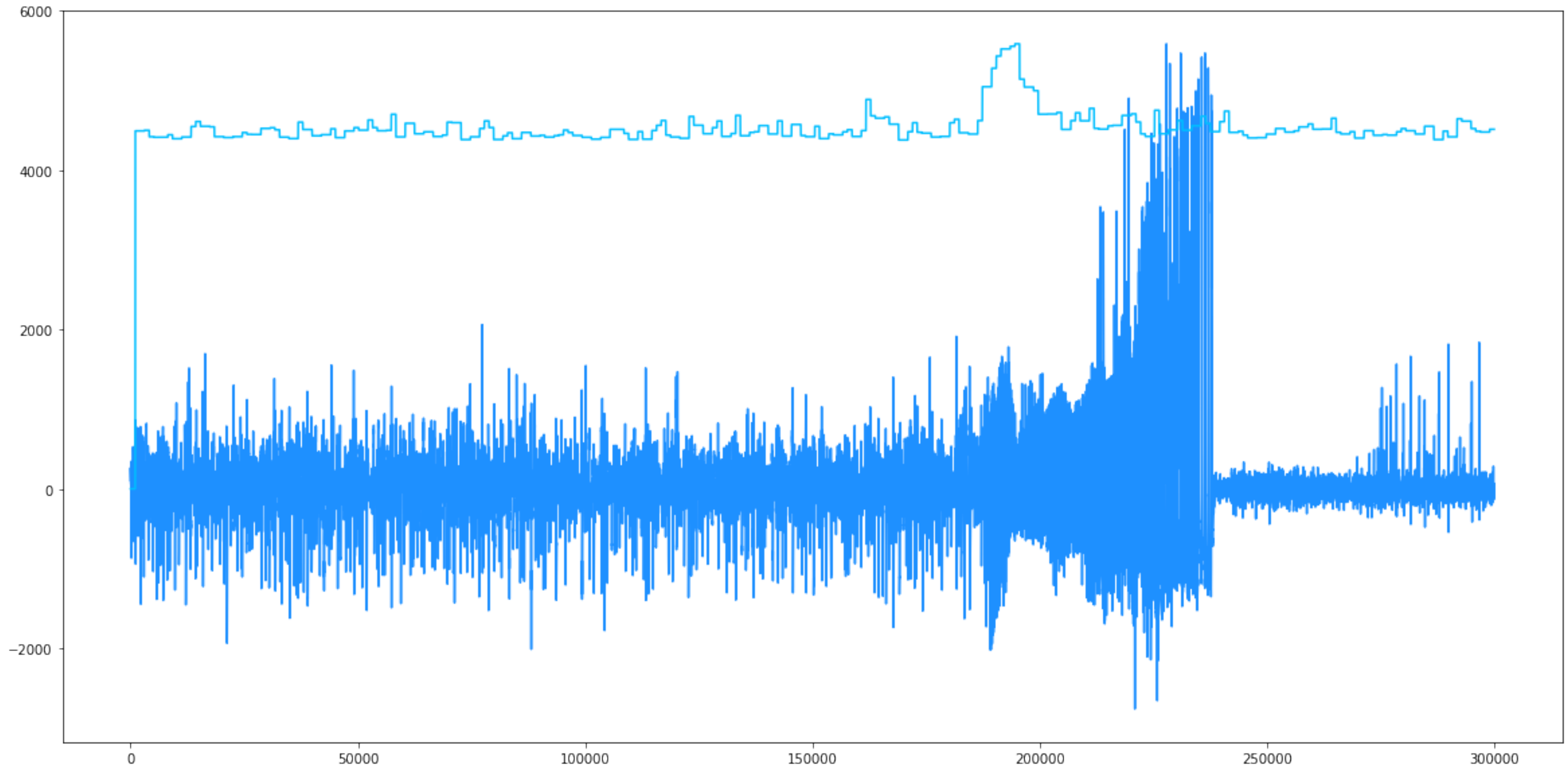


LOCAL BINARY PATTERNS



RESULTS

PHASE SYNCHRONY



RESULTS FOR PATIENTS 1 AND 2

	Patient 1	Patient 2
Min	**6875.6**	**85.7**
Max	10.9	15.8
Moving AVG	31.8	10.4
Energy	23.4	15.7
Line length	48.6	27.9
Kurtosis	28.1	55.8
Skewness	8.4	10.1
Local Binary Pattern	**201.5**	**166.3**
Phase synchrony	140.4	32.6

PATIENT 1

	Seizure 1			Seizure 2		
	False Alarms	Delays	Threshold	False Alarms	Delays	Threshold
Min	**76**	6.1	**0.151**	**76**	6.9	**0.151**
Local binary pattern	**2658**	**0.0**	**0.81**	**3216**	6.0	**0.80**
Skewness	2469	1.2	**0.32**	92	0.1	**0.55**

PATIENT 2

	Seizure 1			Seizure 2		
	False Alarms	Delays	Threshold	False Alarms	Delays	Threshold
Local binary pattern	**157**	**0**	**0.75**	**108**	**3**	**0.77**
Min	2024	8.7	**0.19**	2024	0.87	**0.19**
Skewness	3965	2	**0.30**	378	0	**0.50**

CONCLUSION

SUMMARY

- We have seen how machine learning can help seizure detection
- Why feature selection is a key issue for doing seizure classification
- How the proposed method can help measuring how good is a feature for a given patient regarding our key metrics