Enhancing the Reliability of Epileptic Seizure Alarms for Scalp EEG Signals

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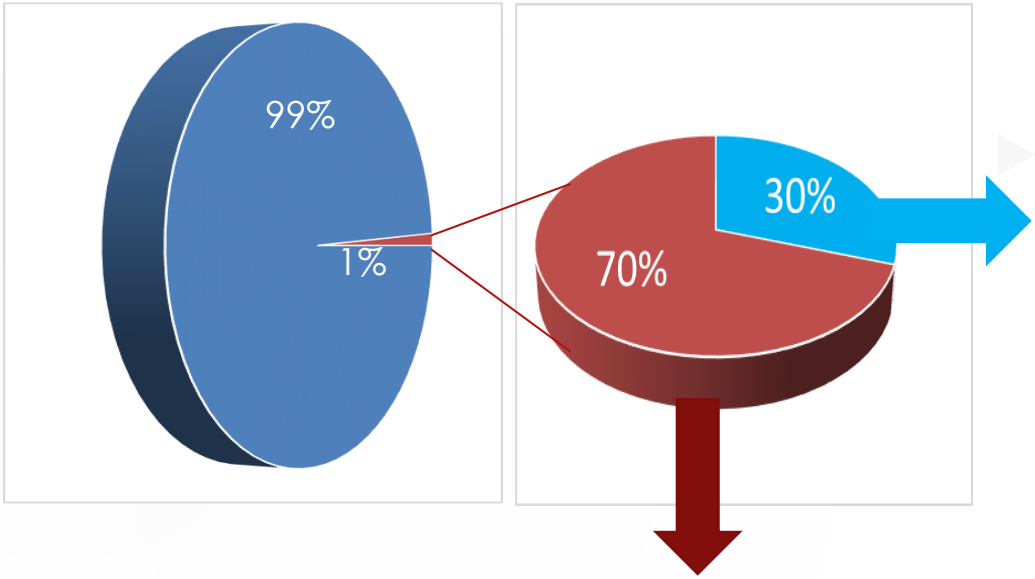
Outline

- Epilepsy
- Epileptic Seizure
- EEG
- Intracranial EEG
- States of EEG
- Prediction of Seizure
- Largest Lyapunov Exponent
- Energy Ratio Algorithm
- Results

Epilepsy

- Serious neurological disease, usually diagnosed when a person has more than one seizure



- Cannot be treated with medications or surgery
- Can be treated with medications or surgery
- About 50000 people are epilepsy patients in Saudi Arabia

Epileptic Seizure

- An epileptic seizure is a brief episode of signs due to abnormal excessive or synchronous neuronal activity in the brain.
- Patients may experience

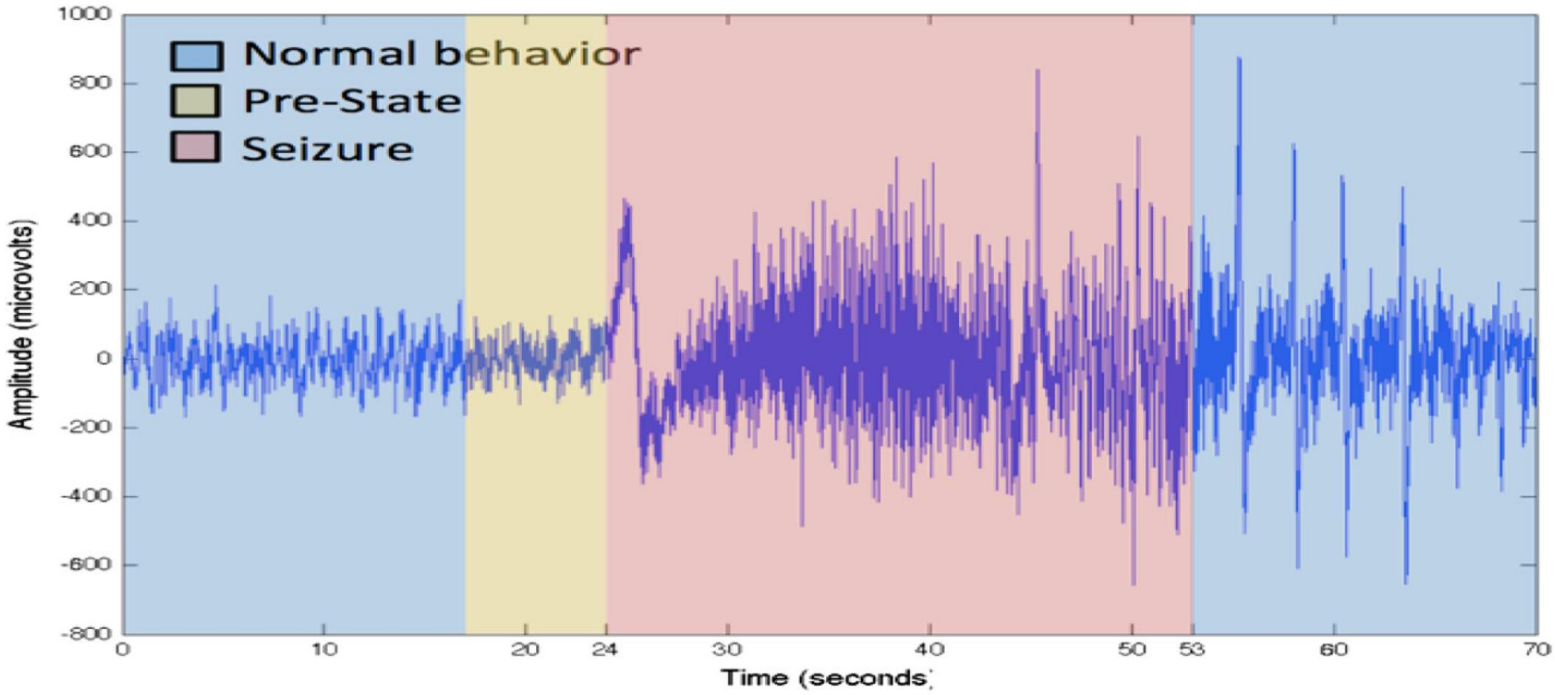
Uncontrolled jerking movement

Momentary loss of memory

- Precautions have to be taken care by these patients while driving or using heavy machinery.

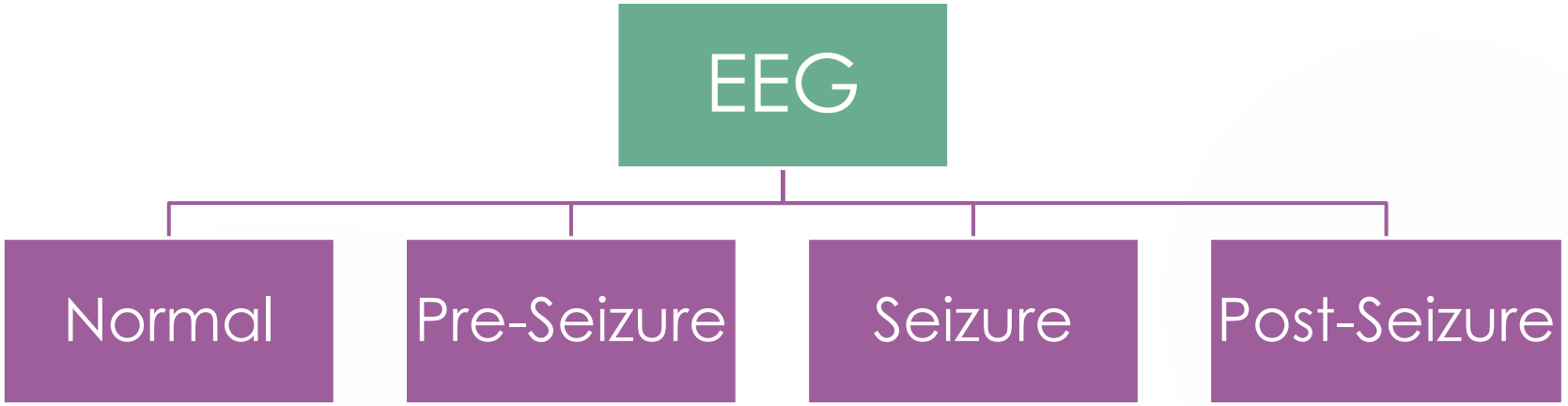
Scalp EEG (electroencephalogram)

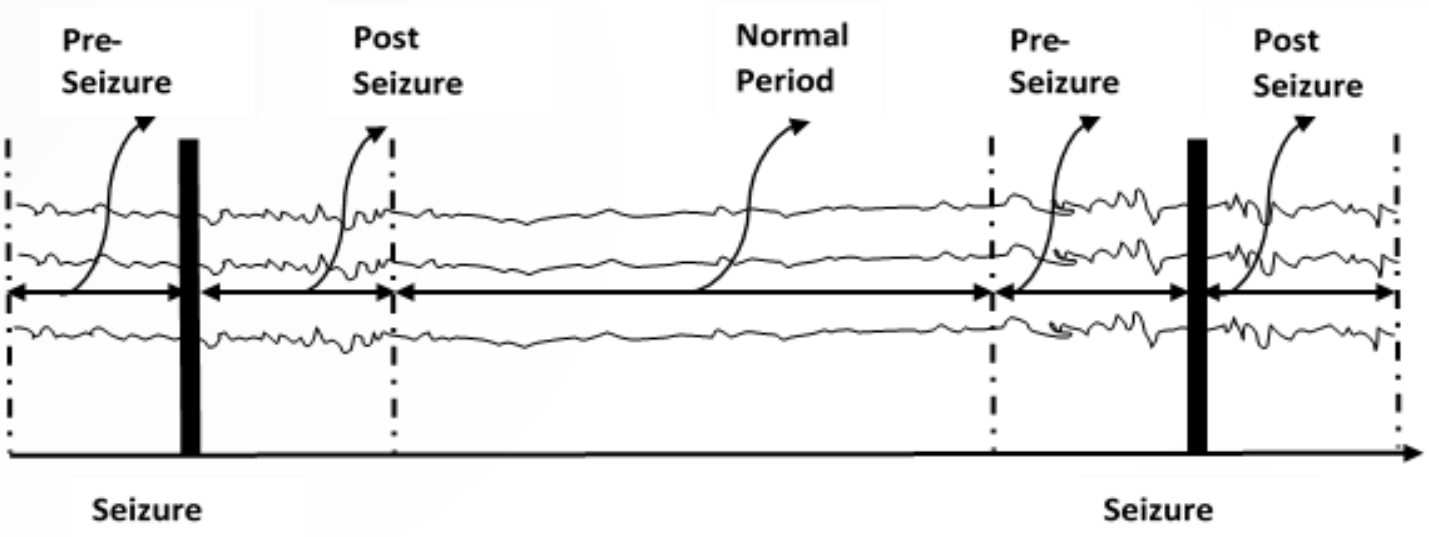
- An electroencephalogram (EEG) is a test that detects electrical activity in your brain using small, flat metal discs (electrodes) attached to scalp.



An EEG signal containing a seizure

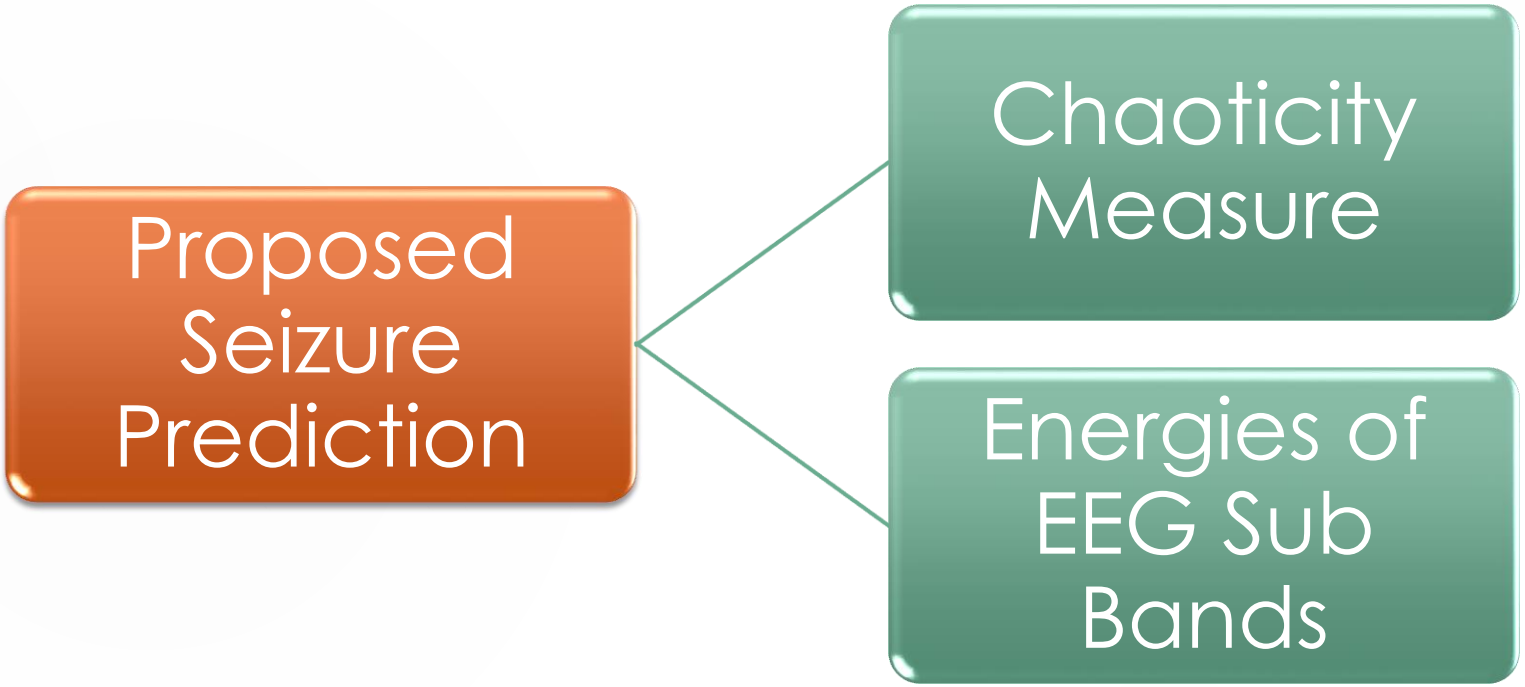
States of EEG Signal





Prediction of Seizure

- Prediction of epileptic seizures is a very active area of research. It requires high accuracy and low false alarm rate.



Chaoticity for Seizure Prediction

- EEG signal is less chaotic during the pre seizure period as compared to the normal period.
- Exploiting this property of the EEG signal will help in the development of seizure prediction algorithms.

What is chaos ?

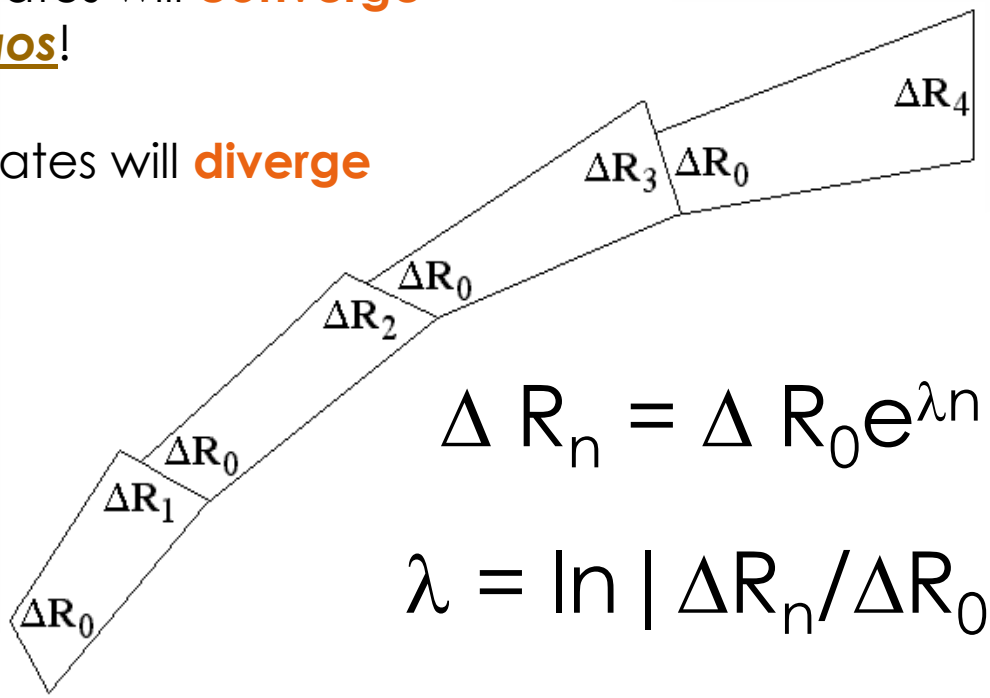
- The property of a complex system whose behavior is so unpredictable as to appear random, owing to great sensitivity to small changes in conditions.

Lyapunov Exponent

The Lyapunov exponent is a measure how quickly two nearby states diverge. If a system is chaotic, the distance between two states will initially rise exponentially after a finite number of steps.

⇒ If **λ < 0**, **n (→ ∞)** the states will **converge**
⇒ ***No Chaos***!

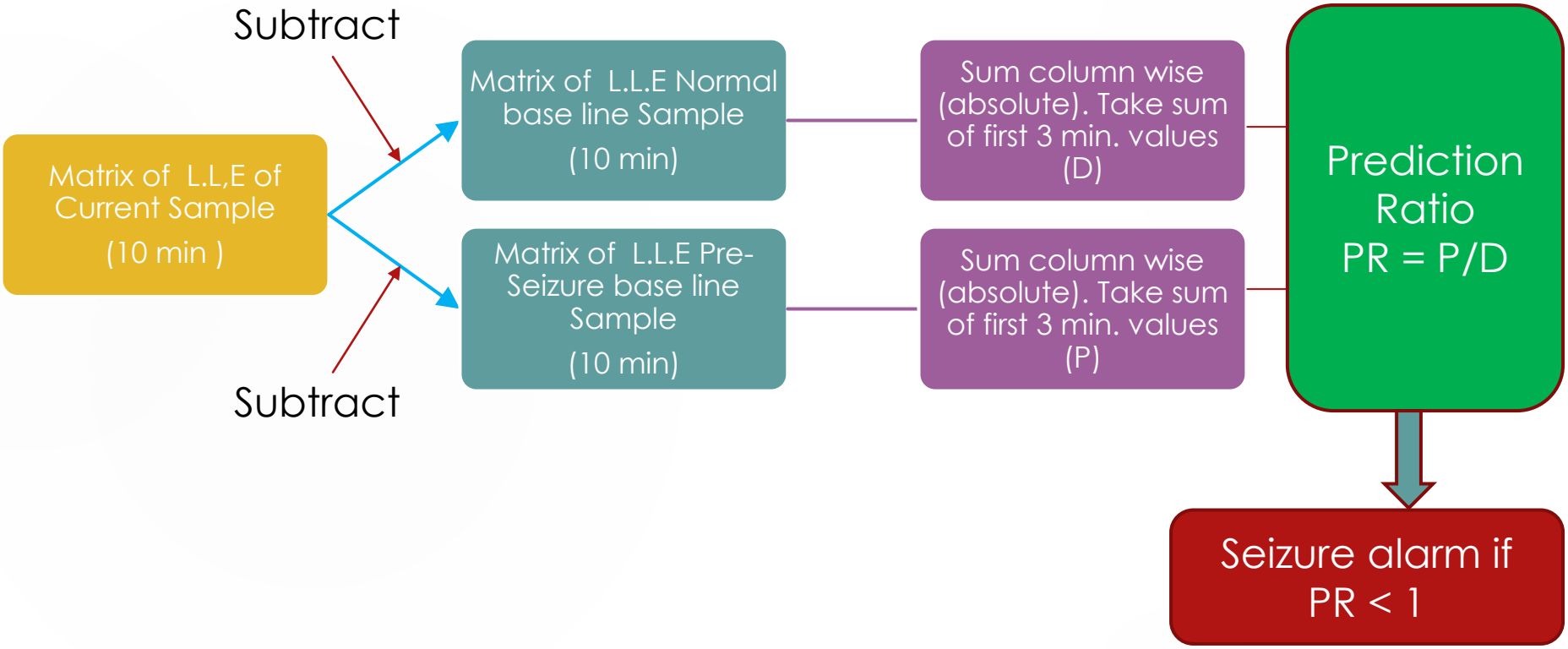
⇒ If **λ > 0**, **n (→ ∞)** the states will **diverge**
⇒ ***Chaos***!



$$\Delta R_n = \Delta R_0 e^{\lambda n}$$

$$\lambda = \ln | \Delta R_n / \Delta R_0 |$$

Largest Lyapunov Exponent (LLE) Prediction Algorithm



Update of Base Line Samples

- If an alarm is initiated while no seizure occurred during H hours following the current window, then the normal baseline samples are replaced with those of current window.
- If no alarm is initiated while a seizure occurred during H hours following the current window, then the pre-state baseline samples are replaced with those of current window.

Energies of EEG Sub Bands

There is a relative decrease in energies of different sub bands of EEG signals during transition from normal to pre-seizure period. We compute the following sub bands energies ratios:

$$R_1 = \frac{E_\Delta}{E_\theta}$$

$$R_2 = \frac{E_\Delta}{E_\alpha}$$

$$R_3 = \frac{E_\Delta}{E_\beta}$$

$$R_4 = \frac{E_\Delta}{E_\gamma}$$

$$R_5 = \frac{E_\theta}{E_\alpha}$$

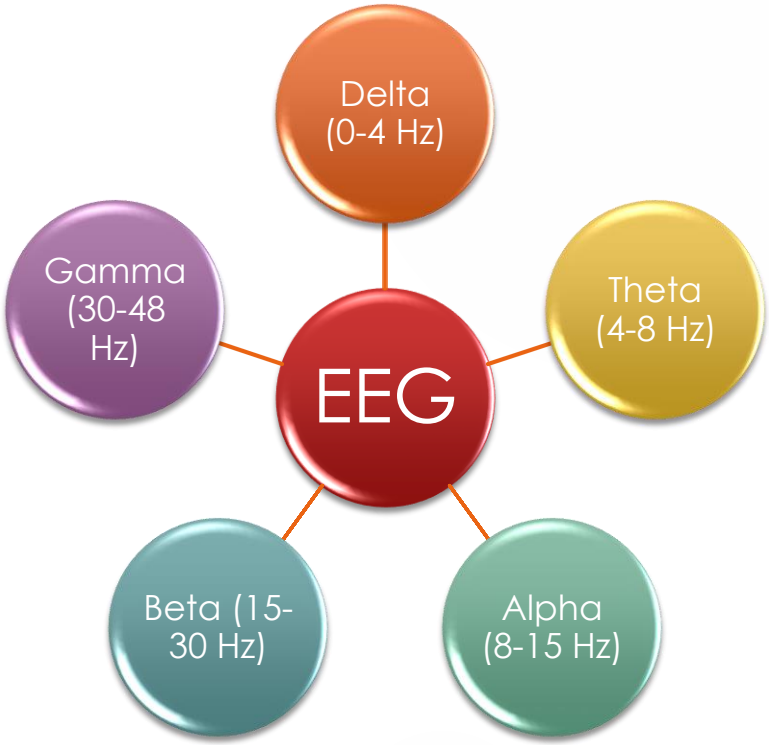
$$R_6 = \frac{E_\theta}{E_\beta}$$

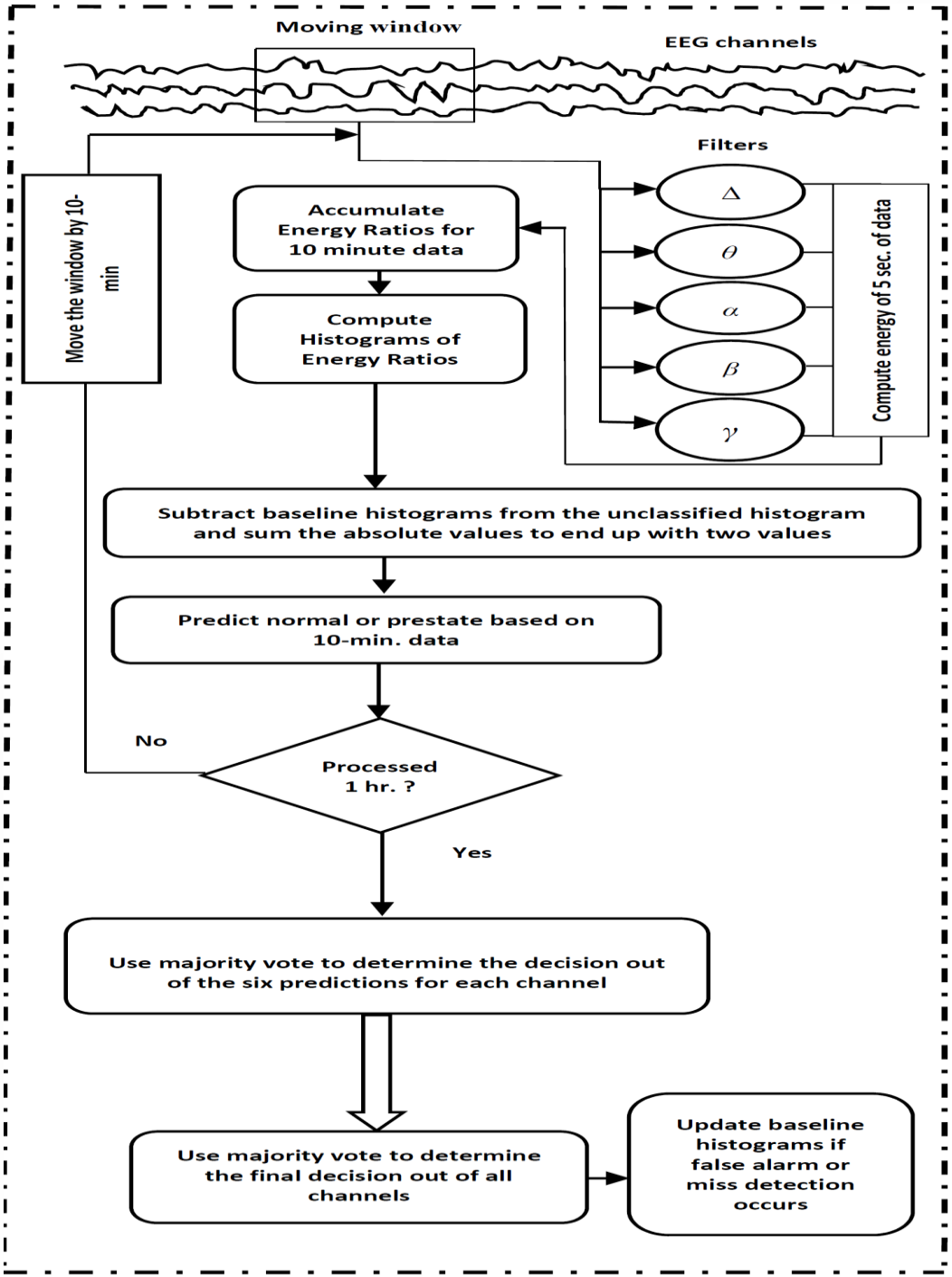
$$R_7 = \frac{E_\theta}{E_\gamma}$$

$$R_8 = \frac{E_\alpha}{E_\beta}$$

$$R_9 = \frac{E_\alpha}{E_\gamma}$$

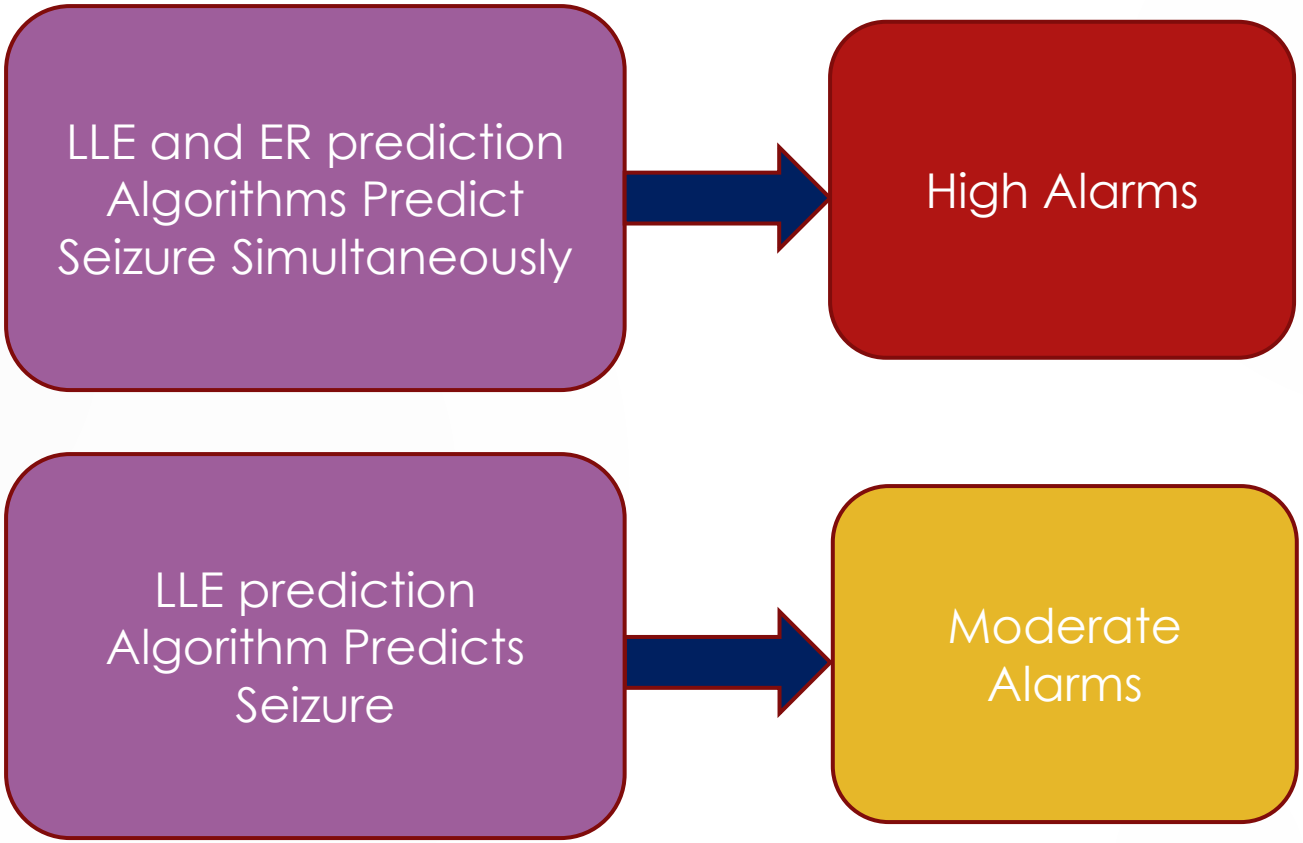
$$R_{10} = \frac{E_\beta}{E_\gamma}$$




Moving window
EEG channels
Filters
Move the window by 10-min
Accumulate Energy Ratios for 10 minute data
Compute Histograms of Energy Ratios
Δ
θ
α
β
γ
Compute energy of 5 sec. of data
Subtract baseline histograms from the unclassified histogram and sum the absolute values to end up with two values
Predict normal or prestate based on 10-min. data
No
Processed 1 hr. ?
Yes
Use majority vote to determine the decision out of the six predictions for each channel
Use majority vote to determine the final decision out of all channels
Update baseline histograms if false alarm or miss detection occurs

Seizure Alarms

- Two types of seizure alarms are generated:



Performance Metrics

Sensitivity = No. of correctly predicted seizures/total number of seizures

Specificity = 1- (falsely seizure awaiting period/normal period)

Results of LLE and ER Prediction Algorithms

Patient No.	Number of			Sensitivity		Specificity	
	Channels	Hours	Seizures	LLE	ER	LLE	ER
1	23	46	7	0.86	0.57	0.91	0.86
2	23	35	3	1	0.67	0.82	0.85
3	23	38	3	1	1	0.90	0.92
4	23	39	5	0.8	0.60	0.89	0.92
5	23	38	7	0.86	0.71	0.96	0.90
6	23	29	5	0.8	0.4	0.96	0.89
7	28	60	1	1	1	0.86	0.86
8	28	42	8	0.87	0.62	0.90	0.90
9	28	30	3	1	1	0.86	0.83
10	28	34	5	1	1	0.93	1
Total		391	47				
Average				**0.91**	**0.76**	**0.90**	**0.89**

Results of LLE and ER Prediction Algorithms

Patient No.	No. of seizures predicted by LLE and ER Simultaneously	No. of alarms with high alerts		No. of alarms with moderate alerts	
		True	False	True	False
1	4	4	0	2	6
2	2	2	0	1	6
3	3	3	0	0	6
4	3	3	0	1	4
5	5	5	0	1	4
6	2	2	0	2	2
7	1	1	0	0	10
8	5	5	0	2	4
9	3	3	0	0	11
10	5	5	0	0	7
Total	33	33	0	9	60
Average	**33/47**	**33/47**		**9/47**	

Conclusion

Experimental results obtained from the processing of scalp EEG signals of 10 patients show that

- When LLE and the newly developed ER algorithms generate seizure alarms simultaneously then the chance of seizure occurrence becomes very high.
- And the false alarm rate for this condition is considerably reduced.

Thanks