

Measuring Entropy in Sleep EEG to Examine Complexity and Level of Biological Activity in Different Sleep Stages

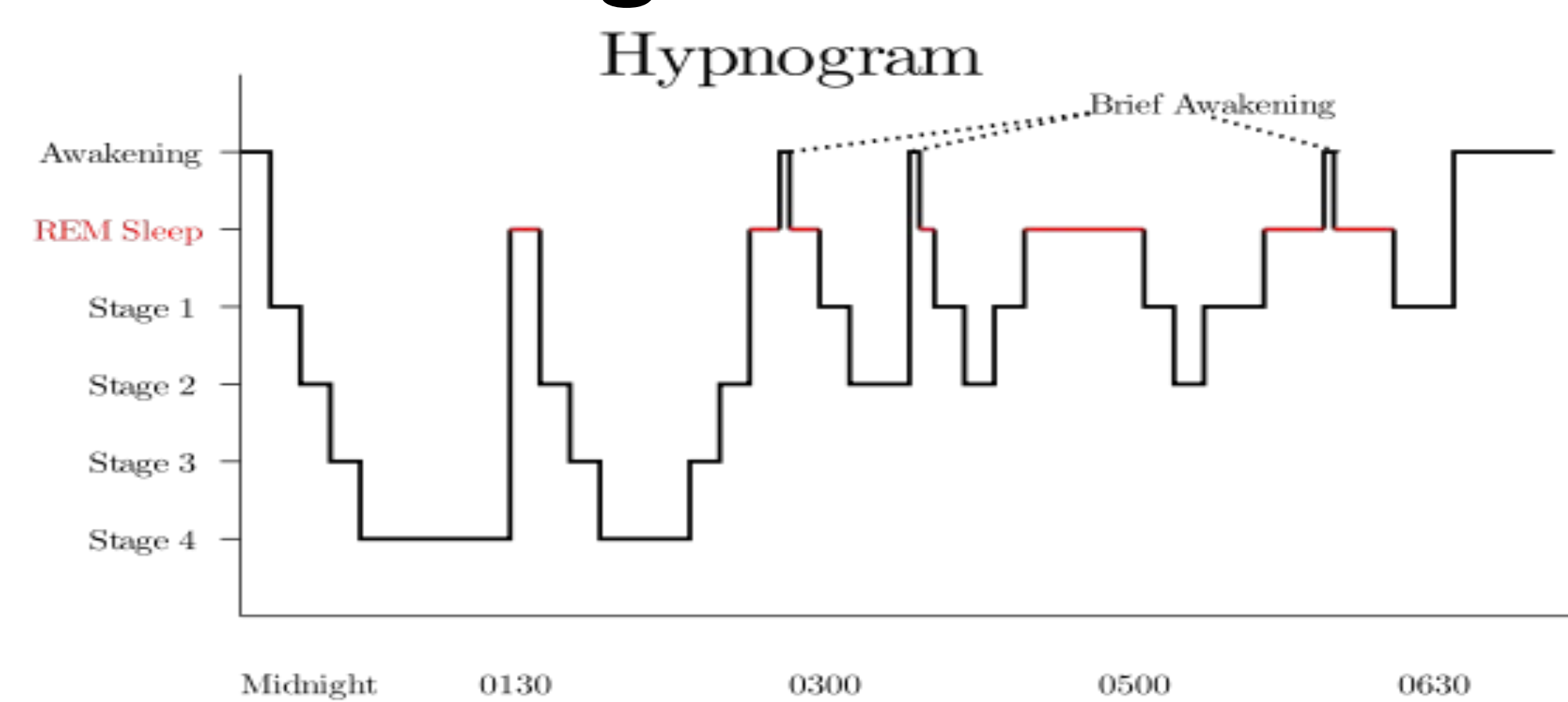
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Introduction

- The objective of this work is to integrate scientific research and engineering principles to advance Engineering Education.
- The research project is, therefore, to evaluate less complex biological systems that tend to have reduced entropy.
 - EX: A person whose heart is unhealthy will have a lower amount of entropy in their cardiac cycles compared to someone with a healthy heart.
- Objective: To further examine this theory the sleep data of many subjects was examined using electroencephalogram (EEG) to determine entropy as a person falls into deep sleep.
- Sleep scoring can help identify sleeping disorders, like insomnia.

Figure #1

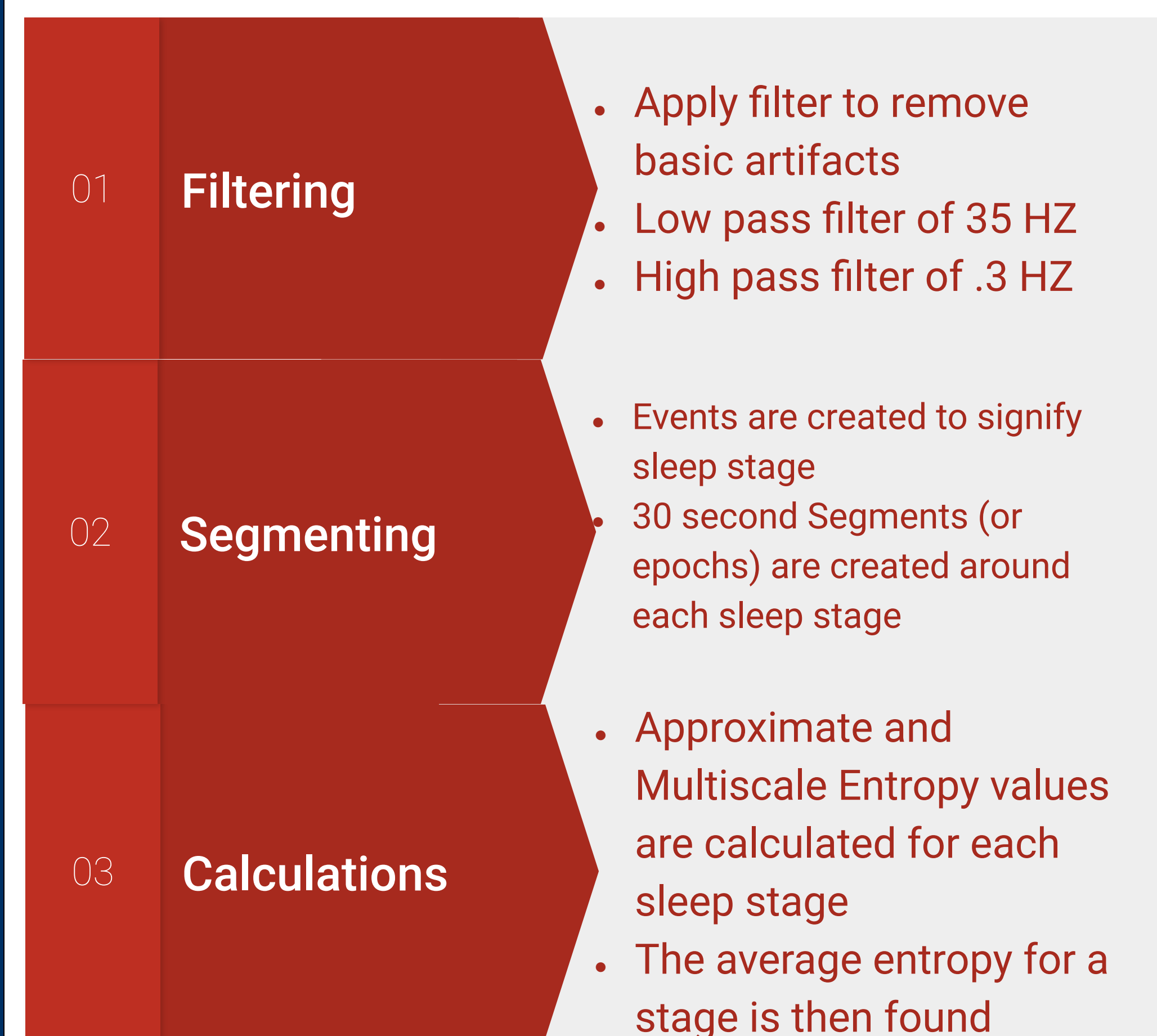


1.Example of sleep scoring

- Sleep Stages
 - W: Wakefulness, when a person is awake.
 - N1/N2: Represent light sleep
 - N3/N4: represent deep sleep
 - R: Rem cycle where a person dreams heaviest. High-rate body movement, eye movement, and heart rate.
- Entropy
 - Approximate Entropy (ApEn) : Calculates the number of similar values between two sequences to find repetitive patterns. More repetitive patterns mean less entropy.
 - Multiscale Entropy (MSE) : Calculate entropy over multiple time scales which are created by averaging a series of data points.
 - EX: $(X1 + X2)/2$

Engineering Procedures

- Matlab and its plugin EEGLAB is used to import data, process it, and calculate the entropy values.
- Subject data is obtained from the publicly available Sleep-EDF Database Expanded, which contains roughly 20 hours of EEG recording for 153 different recordings total.

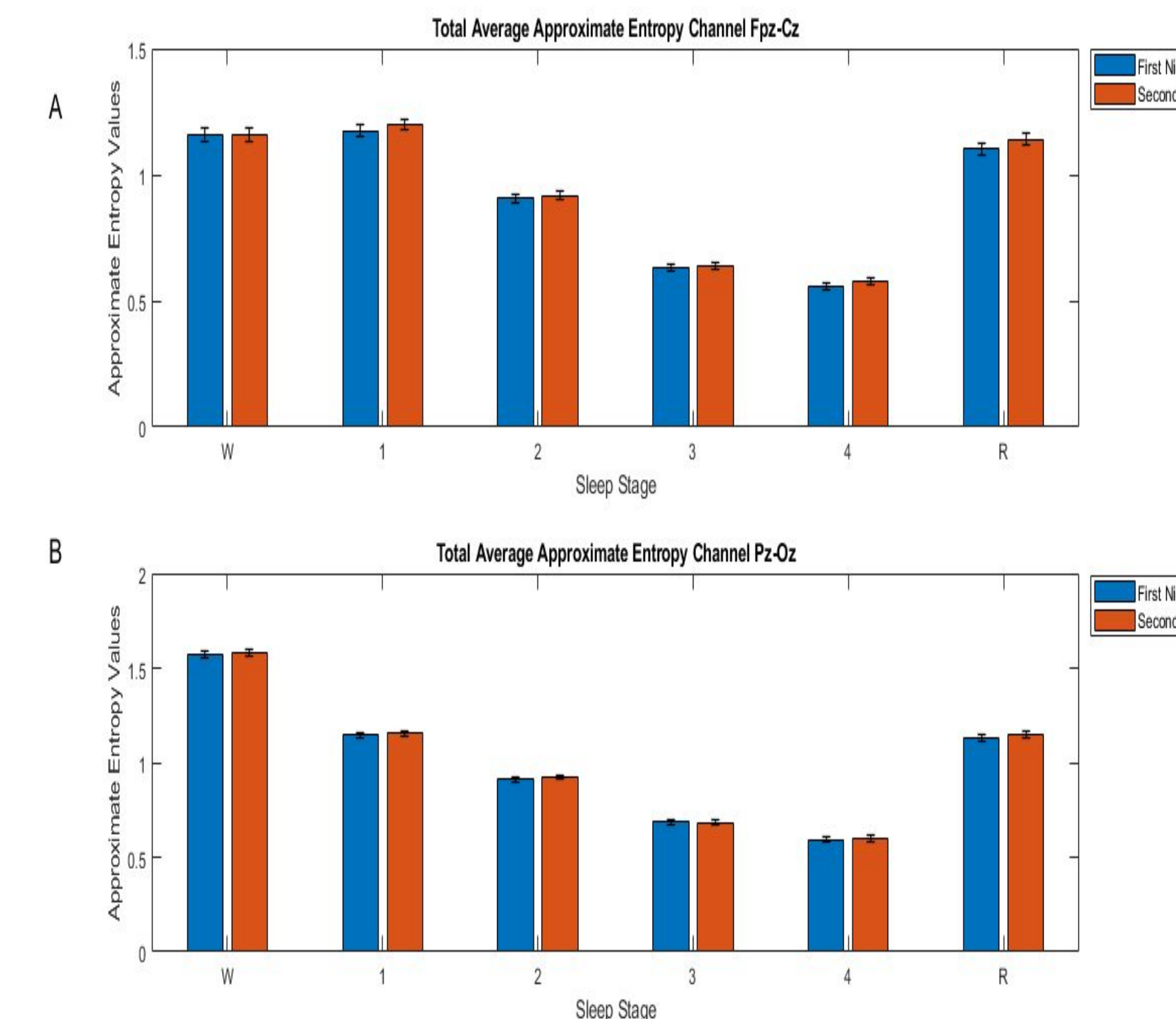


- The method outlined above is mainly based on fundamental engineering principles that is typically required for analyzing Engineering problems.

Results and Engineering Data Analysis

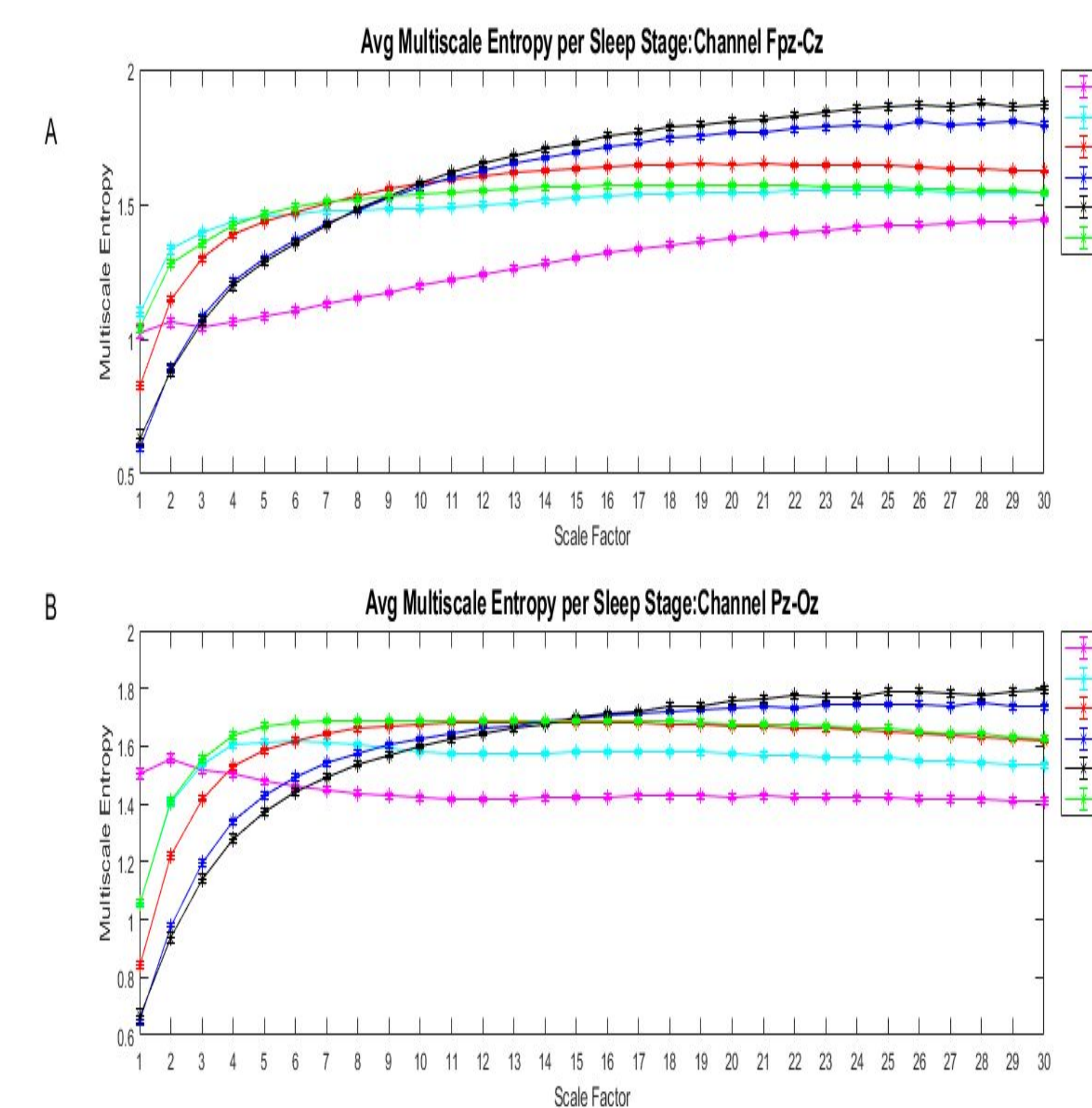
- Sleep stage 1-4 show progressively lower approximate entropy values, until sleep stage R, where it increases as shown in figure 2.
- Multiscale entropy follows the same trend for the first few scale factors before reversing towards the end as shown in figure 3.
- This reversal in entropy may hint at hidden complexities in deeper stages of sleep that may reflect important brain activity.

Figure #2



2.(A).Average Approximate Entropy for channel Fpz-Cz for each night.. (B) Average Approximate Entropy for Chanel Pz-Oz for each night. Error bars represent standard error.

Figure #3



2.(A).Average Multiscale Entropy for channel Fpz-Cz for each stage across scale factors. (B) Average Multiscale Entropy for Chanel Pz-Oz for each stage across scale factors.

Conclusions

- Approximate Entropy results are mostly consistent with the level of activity observed in each sleep stage with deeper levels of sleep corresponding to lower levels of entropy.
- Multiscale Entropy reveals a potentially more complex system at play with deeper stages in sleep.
- The correlation between sleep stages and entropy can be used for automated sleep scoring by providing features that help identify individual sleep stages. This may also prove useful in the training of sleep technicians by providing a method of checking their hypnograms with an external source.
- This will also improve the knowledge and education of sleep technicians and engineers, providing them with new methods of analyzing sleep.
- The learning components from this research are: (i) Application of Engineering Principles and Procedures and (ii) Engineering Data analysis.
- For the advancement of engineering education, future projects may apply this research to further the technique of sleep scoring and diagnosis.

Bibliography

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