Enhancing EEG-based Imagined Speech Recognition through Spatio-Temporal feature extraction using Information Set Theory

Ashrith Sagar Yedlapalli **Prof. Jeevan Medikonda**

Department of Biomedical Engineering,
Manipal Institute of Technology, Manipal, India

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Introduction

Project Objectives

- Conduct a EEG Imagined speech **phonological classification**
- Extracting **rich spatio-temporal features** using Information Set theory

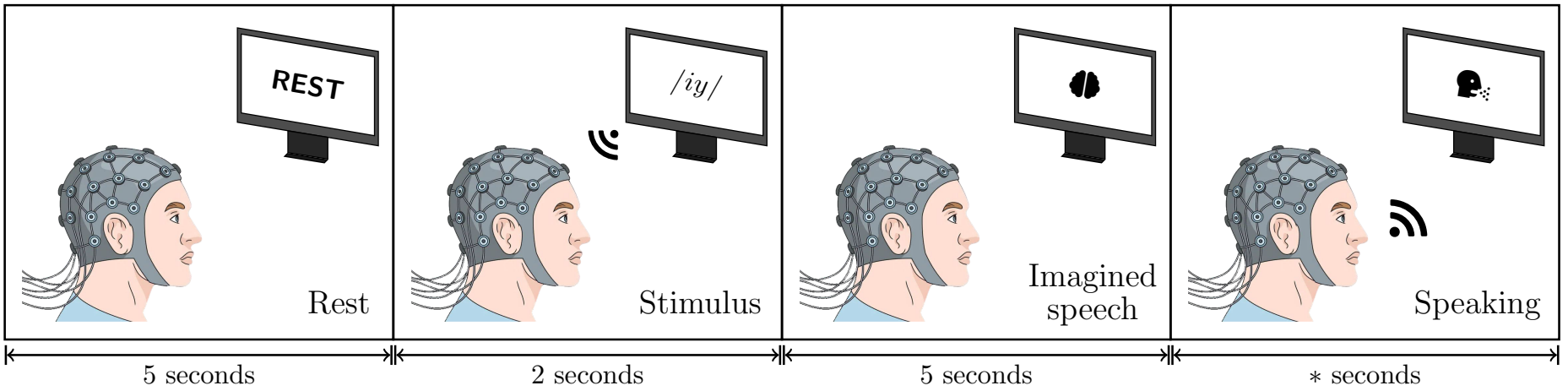
Electroencephalography (**EEG**) and **Imagined/Silent Speech** (SS)

- **EEG** $\rightarrow$ A non-invasive brain activity recording method.
- **SS** $\rightarrow$ Speech silently formed in the mind *without verbal articulation*.
- Advantages of EEG-based BCI:
  - **Non-invasive** and easy to use.
  - **Good temporal resolution**.
- **Challenges** in SS recognition using EEG:
  - Low Signal-to-Noise Ratio (SNR).
  - Limited spectral and spatial resolution.
- **Limitations** of current techniques:
  - Selecting subset of features based on *Pearson correlation coefficients* between EEG and Audio segments.

Methodology

KaraOne database

- Data from **3 modalities**: **Acoustic**, **Facial**, and **EEG data**.



Each trial for each subject consisted of **four states**: *rest*, *stimulus*, *imagined speech*, and *speaking*.

Data cleaning
BPF, ICA, BSS
1. Signal filtering
2. Noise removal, Improve SNR

→

Effective information
1. Information sets
2. Gaussian membership functions
3. Temporal and spatial dimensions

→

Model development
SVM, RF, kNN, ...
1. Feature extraction
2. Feature selection

Figure: Overview of the methodology

Methodology

Extracting **Effective information** — Information Sets

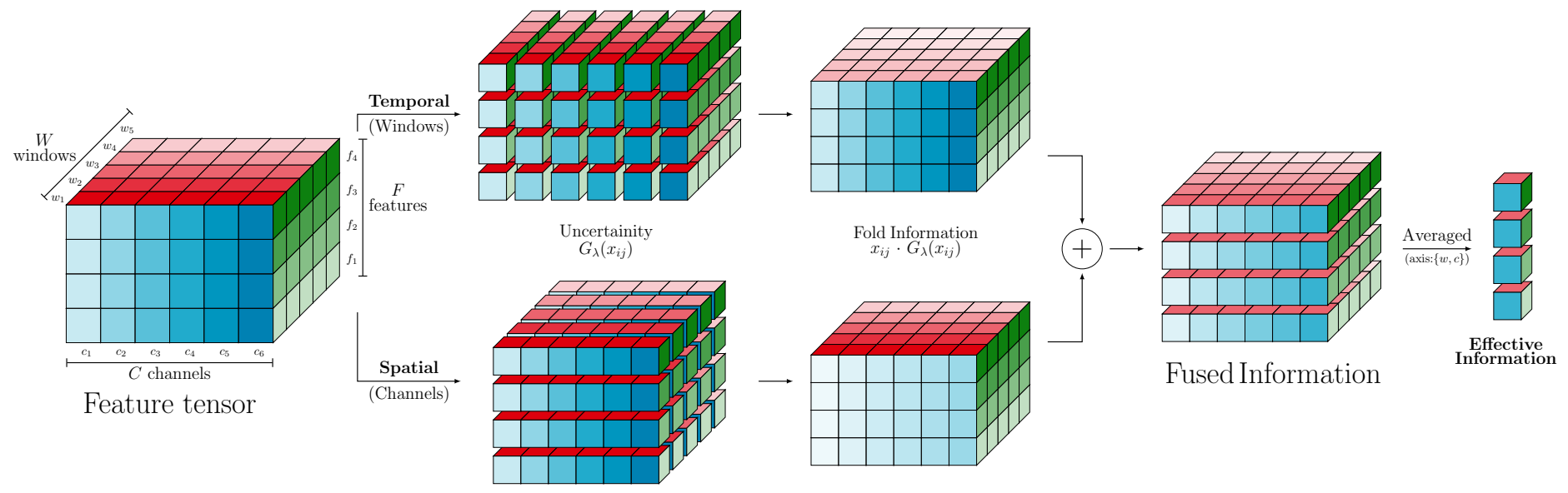


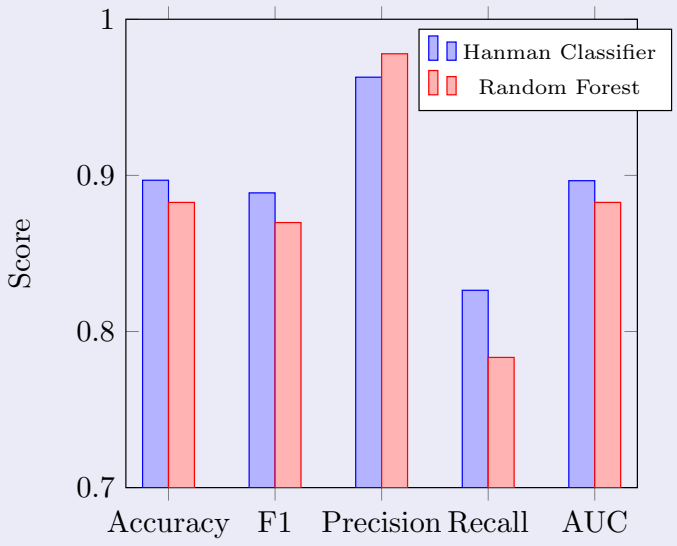
Figure: Extracting effective information from the features across both **temporal** and **spatial** dimensions resulting in rich spatio-temporal features.

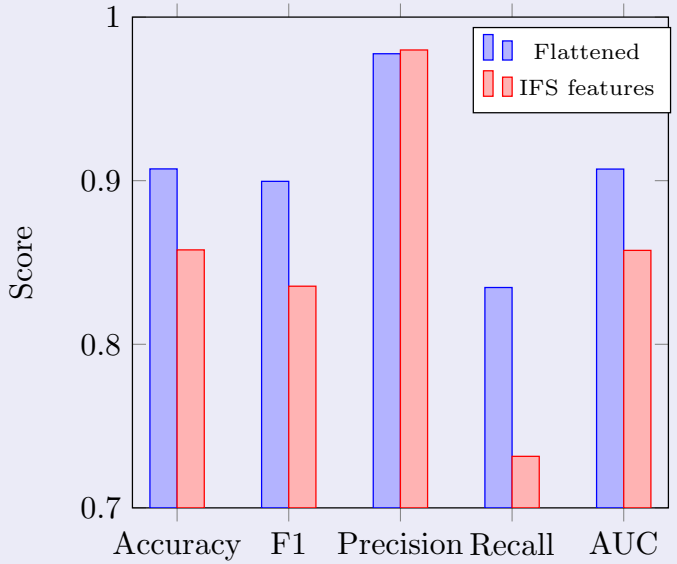
- Effectively **reduces** $[W \times C \times F]$ feature matrix to a F-**length** feature vector.
- Contrasted with **selecting top** k **features** via *Pearson correlation coefficients* between EEG and Audio segments.

Key results & Learnings

Performance metrics

- The study aimed to enhance EEG-based imagined speech recognition.
- About 6% *absolute increase* in all metrics observed.





Learnings

- Importance of **feature selection** in improving classification accuracy.
- Challenges encountered in **preprocessing EEG data**.
- Signal processing techniques on **enhancing SNR** in EEG.
- Insights gained into the **limitations** of existing EEG-based BCI paradigms.