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# Attribute Ranking for Lateralizing Focal Epileptogenicity in Temporal Lobe Epilepsy

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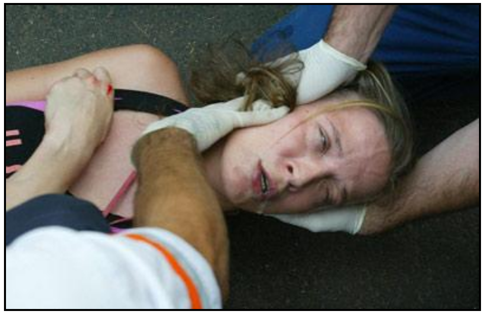
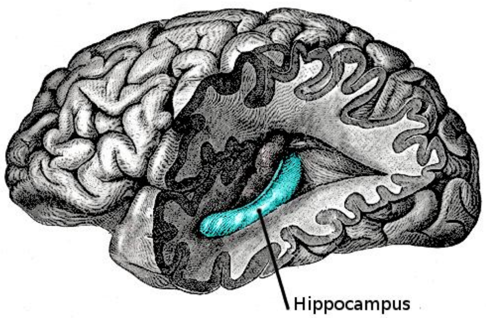
# Temporal Lobe Epilepsy (TLE)

- **Epilepsy** is a brain disorder involving repeated, spontaneous seizures of any type.
- **Seizures** are episodes of disturbed brain function that cause changes in attention or behavior.
- About **60%** of all adult epilepsy cases are localization-related epilepsies; **Temporal Lobe Epilepsy (TLE) is the most common single form**.
- It is also the **most surgically operated** type.





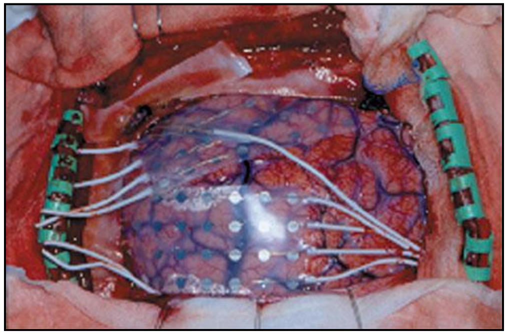
# Treatment

- Begins with **medication**.
- **Surgery** will be considered if patient did not respond to medication.
- **Lateralization** of the seizure focus should be performed before surgery.
- It indicates **which side of the brain** is mostly responsible for the seizure occurrence.

# Phase II Patients (Requiring eECoG)

- **Phase II patients** is referred to a group of patients which **lateralization is not so clear** for them by considering the **usual features.** e.g. EEG, MRI

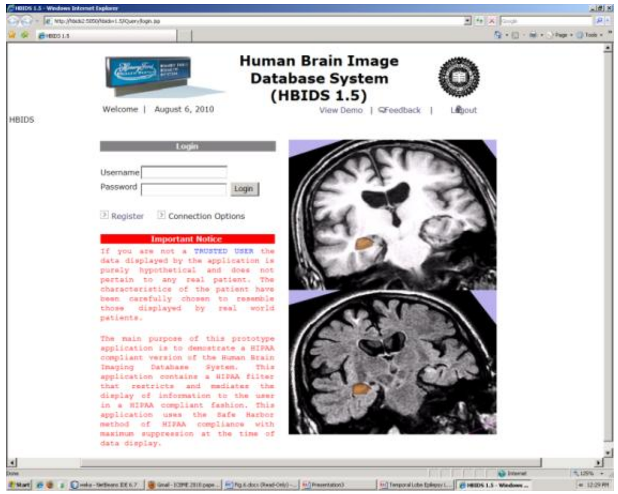
- Phase II Patients are taken to surgery in order to **implant electrodes into their brains.** **[Extraoperative Electrocorticography (eECoG) ]**



# Outcome (Engel Classification)

- The defected temporal lobe is **removed** by surgery.
- Patients are classified into **four groups** based on their **seizure frequency** after surgery, (outcome or successiveness of the surgery)
- **Class I** been the most cured and **Class IV** been the worst.
- **About 30%** of the surgeries will not result in the improvement of the patients condition.

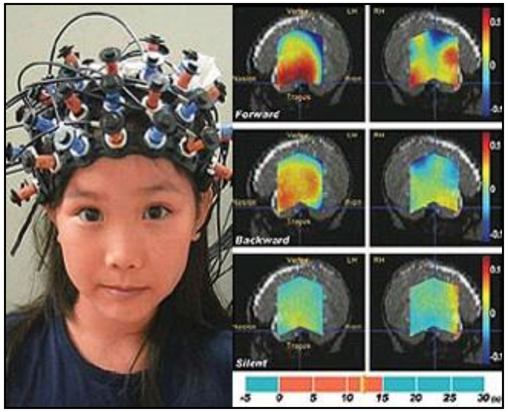
# Human Brain Image Database System (HBIDS)




- Human Brain Image Database System (HBIDS) is a database developed at Henry Ford health system radiology research laboratory which includes many Epilepsy related features of about **145 patients.**

# Some of the Attributes in HBIDS

- Semiology
- Neuropsychological profiles
- Pathology
- EEG Data (including interictal waveforms, their location and predominance as well as ictal onset location.)
- Magnetic resonance (MR) imaging
- Single photon emission computed tomography (SPECT)
- MRI fluid-attenuated inversion recovery (FLAIR) mean signal and standard deviation
- Texture analysis
- WADA test
- Location of surgery
- Outcome according to the Engel classification.




# Attribute Ranking in Biomedical Datasets

- Several diagnostic features from multiple sources results in a **high-dimensional sample spaces**.
- **Irrelevant** features **reduce the accuracy** and reliability of the prediction model.
- **Ranking of individual attributes** is an important aspect of any effort towards computer-aided decision-making.
- Additional benefit of this assessment is the achievement of **knowledge** on the **discriminative value of each feature** with respect to diagnosis.

# Consensus Attribute Ranking

- Ensemble (consensus) methods are used to mitigate the **problems of traditional methods** such as poor accuracy, bias, and stability.

- Since attribute scores are calculated from several sources, consensus feature rankings are **less dependent on prediction models** and do not suffer from classifier bias.

$$FinalScore(f_i) = Combination(score_1(f_i), \ldots, score_n(f_i))$$

# Consensus Attribute Ranking

- To calculate ***score$_i$(f$_i$)***,
  - Individual features were evaluated by building a **single variable classifier**
  - Feature's **predictive performance** is calculated
  - using **leave-one-out cross validation**.

$$FinalScore(f_i) = Combination(score_1(f_i), \dots, score_n(f_i))$$

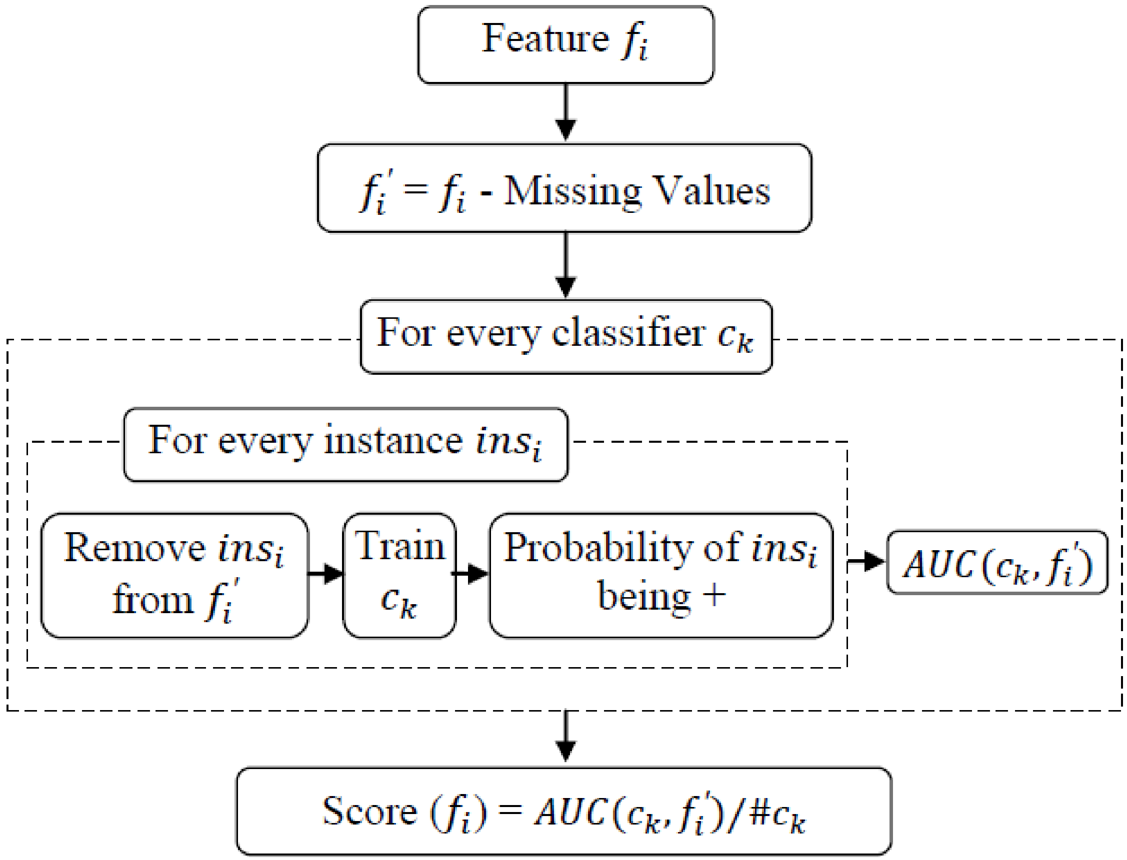
# Medical Datasets

- When applying feature ranking methods on medical datasets, one has to consider the **common characteristics of medical datasets**:
  - Class-imbalanced data
    e.g. Cancer-bearing patients / Healthy people.
  - Missing values
    e.g. not all studies can be necessarily carried out in all patients.
- HBIDS suffers from the same limitations.

# Addressing Missing Values and Class-Imbalance Data

- Missing value **estimation** and imputation negatively affects the **reliability** of the model.
- We performed the study only based on properly recorded values:
  - Missing values were **eliminated**.
  - This adversely affects the imbalance distribution
- For imbalance problem; **Area Under Receiver Operating Characteristic (ROC) Curve (AUC)** was used as a performance evaluator instead of accuracy.

# Ranking Algorithm



# Discriminative Score of Each Feature

- Simplified:

$$D.Score(f_i) = \sum_{c_k \in C} AUC(c_k, f'_i)/5$$

- C = {Decision Trees, Naïve Bayes, Support Vector Machines, 3-Nearest Neighbors, Multilayer Perceptron}

# Experiment Environment

- The dataset used in the following experiments is from HBIDS.
- Only **Engel class I (free of disabling seizures)** patients were selected, to **have a reliable laterality** for the experiments.
  - **89** patients
  - **36 males, 56 females**
  - Average age of **38y** (S.D. 12.2).
  - Temporal lobe epileptogenicity was found to be on the **left** in **47** patients and the **right** in **42** patients.
  - **50** patients lateralized based on **standard noninvasive evaluations,** whereas **39** patients required **eECoG**.
  - **197** medical features.

# HBIDS Missing Values

- Missing values were identified for:
  - **EEG** features in **21%** of cases
  - **Wada** studies in **31%** of cases
  - **Imaging features** in **46%** of cases
  - The **remaining** features in about **20%** of cases on average.

# Experiment I (Attribute Groups in All Patients)

- Which **group of attributes** are more discriminative for lateralization.

- Discriminative score of the **best indicator** in each group was considered the score of the whole group.

$$G.D.Score(G_j) = max(D.Score(f_i)) \mid f_i \in G_i$$

# Experiment I (Attribute Groups in All Patients)

| Group | Best Discriminative Feature | D. Score |
|---|---|---|
| Imaging | Ictal SPECT subtraction (right-left) | 0.88 |
| EEG | Sharp wave 1 activity location (waveform less than 200ms in duration on EEG identified at site 1) | 0.88 |
| Wada | Memory score (right-left) | 0.70 |
| Neuro-psychology | Boston naming test | 0.55 |
| Handedness | Habitual hand used for writing | 0.55 |
| Medication | Medication dosage | 0.50 |
| Seizure description | Aura without seizure (the occurrence of a simple partial event without the succeeding habitual ictus) | 0.54 |
| Medical history | Family history of febrile seizure (seizures with fever) | 0.55 |
| Semiology | Olfactory | 0.53 |
| Age | Age at surgery | 0.49 |
| Exam | Speech dysarthria (poor articulation of speech) | 0.49 |
| Psychiatric history | Past depression | 0.47 |

# Experiment II (Attribute Groups in Phase II Patients)

- **Phase II patients** who underwent **eECoG** for lateralization are included in the investigation.
- As lateralization of phase II patients are harder, predictive power of attributes are reduced.

# Experiment II (Attribute Groups in Phase II Patients)

| Group | Best Discriminative Feature | D. Score |
|---|---|---|
| EEG | Sharp wave 1 activity location (Waveform less than 200ms in duration on EEG identified at site 1) | 0.93 |
| Imaging | Ictal SPECT subtraction (right-left) | 0.79 |
| Wada | Memory score (right-left) | 0.59 |
| Neuro-psychology | Boston naming test | 0.65 |
| Semiology | Olfactory | 0.50 |
| Psychiatric history | Past depression | 0.51 |
| Seizure description | Duration of epilepsy | 0.49 |
| Handedness | Habitual hand used for holding a hairbrush | 0.48 |
| Age | Duration of latency | 0.52 |
| Exam | Motor side (Side of loss of power) | 0.44 |
| Medical history | Family history of febrile seizure (seizures with fever) | 0.44 |
| Medication | Medication frequency (Number of times drug is taken during the day) | 0.44 |

# Experiment III (Imaging Features)

## All Patients

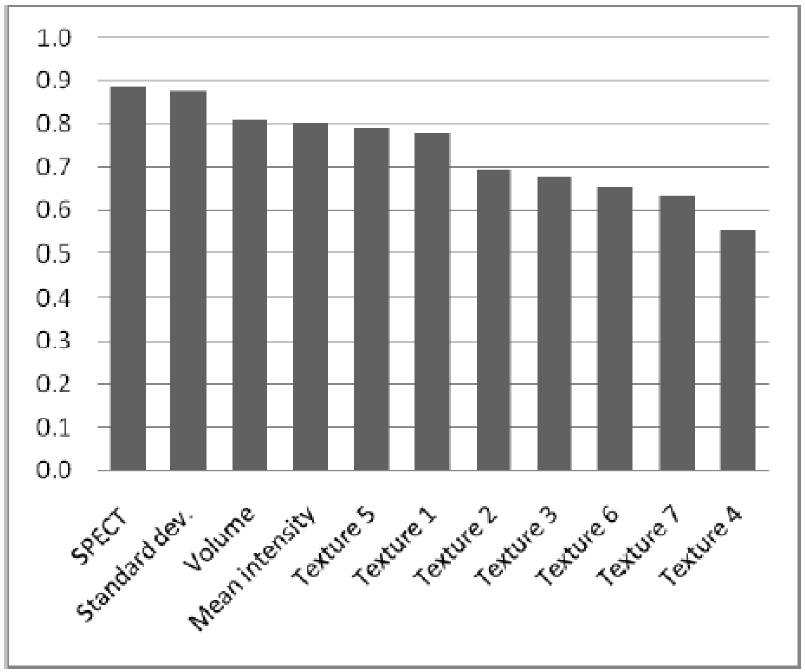



Figure 1. Discriminative power of diagnostic imaging features in all patients (patients lateralized based on standard preliminary investigations and patients lateralized based on eECoG).

## Phase II Patients

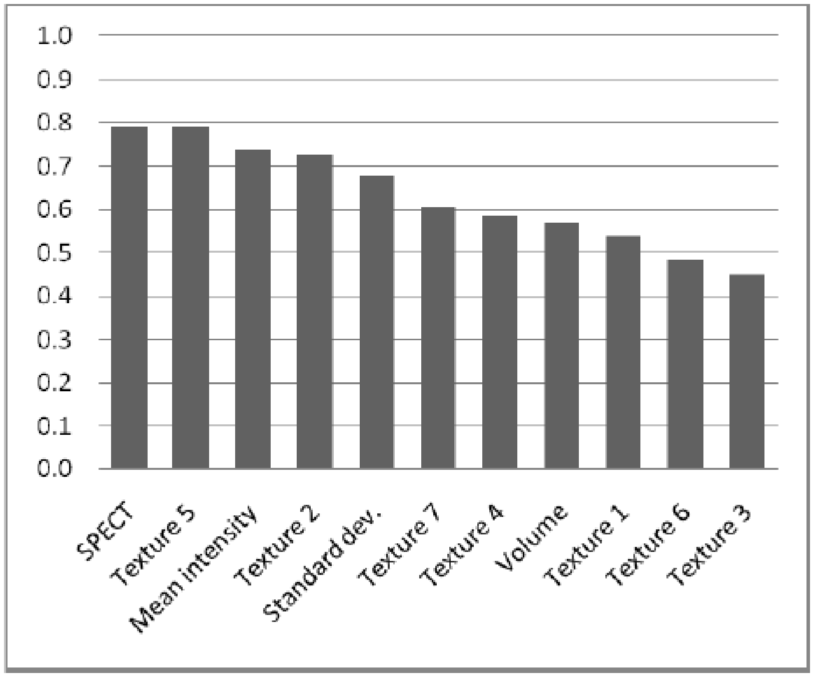



Figure 2. Discriminative power of diagnostic imaging features in patients lateralized based on eECoG.

# Experiment IV (EEG Features)

All Patients


Figure 3. Discriminative power of diagnostic EEG features in all patients (patients lateralized based on standard preliminary investigations and patients lateralized based on eECoG).

Phase II Patients

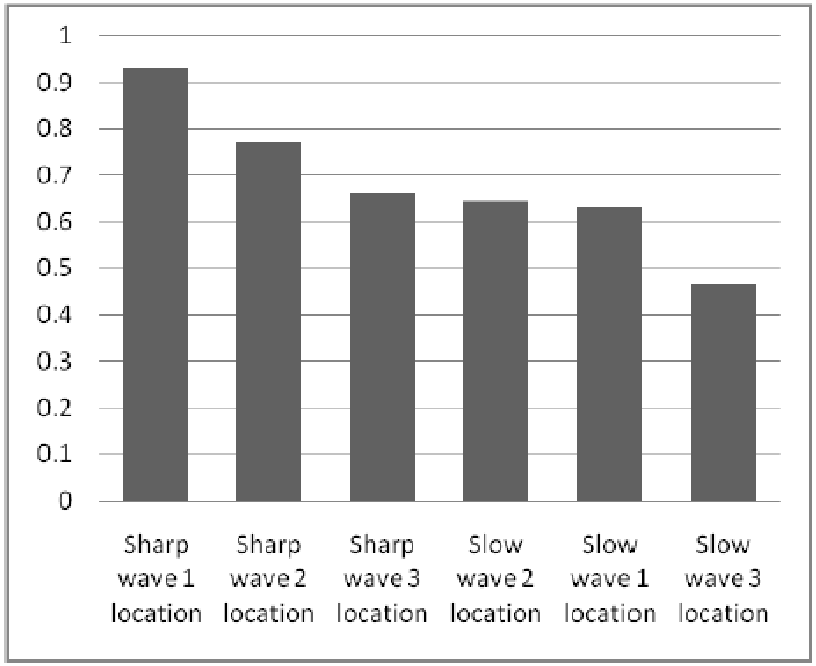



Figure 4. Discriminative power of diagnostic EEG features in patients lateralized based on eECoG.

# Observations and Conclusion

- **Electrographic** and **imaging attributes** have the highest discrimination of laterality;
  - Despite symmetry of hippocampal volumes in a significant number of patients.

- **High average AUC** in some features for **phase II** patients suggests that **avoidance of eECoG would have been possible in a number of cases**.

- Data mining and pattern recognition methodologies are shown to be **beneficial** in the **identification of laterality** and **in potentially reducing the requirement for eECoG.**

# Thank You!