Brain Centers Model and Its Applications to EEG Analysis
Ideas and First Experiments

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Outline

1 Existed Psychophysiological Models

2 Model Description
   - Model Requirements
   - Model Assumptions
   - Learning procedure

3 First Experiments
   - EEG Reproduction
   - Functional State Identification

4 Applications and Further Research
Existed Psychophysiological Models

Models that explains mental effects by interaction between different centers:

Figure: Model of brain structure interaction during emotional following of behaviour act

Figure: Model of reentry stimulation on pattern recognition

These models are constructed theoretically and have different untestable beliefs as foundation. These models cannot be verifying by physiological methods.
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Model Requirements

Solution

We use a fixed-structured Neural Network model:

1. fixed structure provides a good physiological interpretation as a model of brain processes
2. can reflect the intrinsic properties of EEG data and so it can be used for functional state identification

1. Functional State Identification Ability
2. Physiological Interpretation and Model Empirical Testability
Model Requirements

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Model Assumptions

Figure: Brain Centers Model with 2 centers

Neural Network traits:

1. **Feed-Forward** network with $n$ inputs and $n$ outputs
2. It has **four** layers for good physical interpretation
3. Activation function is **bipolar sigmoid** for activating or inhibiting connections between centers

Assumptions and Ideas

1. Electric potentials captured by electrodes are result of an interaction between brain centers
2. Input and output layers represent the electrodes that register the EEG data
3. Two hidden layers represent the brain centers with some interaction structure between (corresponding synaptic weights) $\Rightarrow$ each center is represented by two neurons
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4. Output electric potentials and brain centers have cross-effect. This cross-effect is represented by first hidden layer inputs (effect on brain centers) and second layer outputs (effect on electric potentials)

5. This influence is static $\Rightarrow$ synaptic weights of first hidden and output layers are constant (don’t change during learning phase) $\Rightarrow$ neural network learning procedure should be modified
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Learning procedure of model is based on error back propagation method. Model uses next modifications:

1. input layer synaptic weights are kept constant during learning
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Figure symbols:
- synaptic weight is constant during learning phase
- synaptic weight varies

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First Experiments

Data

Data is EEG of a person in different functional states:

1. eyes were opened (Opened Eyes data)
2. eyes were closed (Closed Eyes data)
3. person was watching fractal pictures (Fractal data)

Data Processing: artifacts deleting, reasonable filtering and smoothing
**EEG Reproduction**

**Goal:** starting learning phase with some probably arbitrary initial input, reproduce EEG signals

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**Results**

Achieved correlation between original EEG time series and its reproduction by Brain Centers Model:

1. **Fractal data:** $0.896 \pm 0.001$
2. **Open Eyes data:** $0.881 \pm 0.002$
3. **Closed Eyes data:** $0.836 \pm 0.007$
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Functional State Identification

Goal: giving weights of Brain Centers Model instances those were trained on different EEG data, identify different functional states

Results

1. Left plot: principal components of brain centers interaction schema in the case of random three second cuts of the EEG recordings ⇒ noisy functional state in long EEG time series (17 seconds)

2. Right plot: in the case of first three second cuts of the EEG recording
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Medical Applications

- Pathology Detection
- Localization of Brain Centers
- Brain Exploration
- Brain Centers Interrelation Exploring

Current State Specificities Analysis
Functional State Monitoring
Functional State Identification
Brain Centers Model
Further Research

Open problems

1. Brain centers localization with respect to constant weights matrix that should be of full rank
2. Choosing of initial input and its modifications during brain centers model learning phase

Functional State Identification

1. Using of different machine learning techniques for state identification efficiency improving
2. Comparing results of brain centers model with other methods of EEG analysis and neuro-visualization

Non-medical applications

The idea of brain centers model for data compact representation can be used for efficient solving of different tasks. For example, non-medical pattern recognition such as text classification (where centers with interaction schema can be thought as general semantic network for specified text categories)
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THANKS FOR ATTENTION!