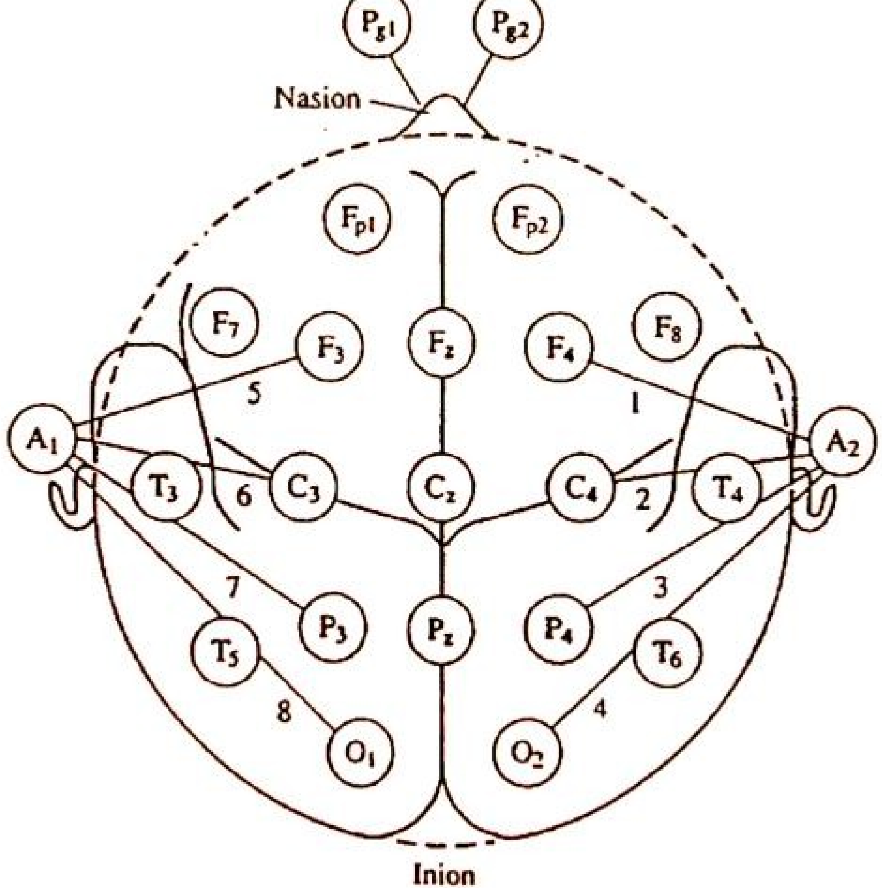
Biosignals and Systems

Lecture 5

EEG

Brief introduction to the EEG

The EEG signal is measured with Ag-AgCl electrodes which are placed in standard positions on the scalp (signal is <100μV due to skull attenuation)



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Characteristics of the EEG

- The important information is in the *frequency* domain.
- The frequency range from 0.5 to 30 Hz has been arbitrarily divided into 5 bands:
  - Delta 0.5-4Hz
  - Theta 4-8 Hz
  - Alpha 8-13 Hz
  - Beta 13-22 Hz
  - Gamma 22-30 Hz

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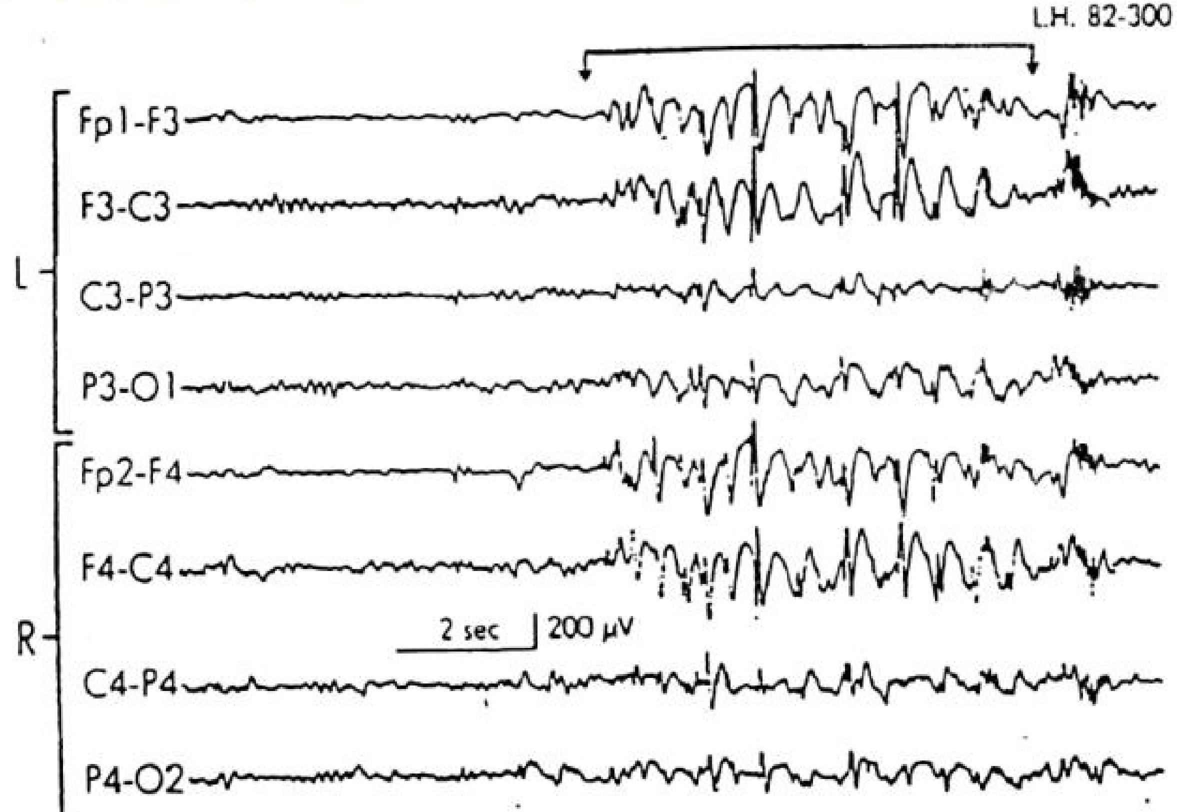
Diagnostic uses of the EEG

EEG analysis helps in the diagnosis of brain death, epilepsy and sleep disorders



EEG during an epileptic seizure

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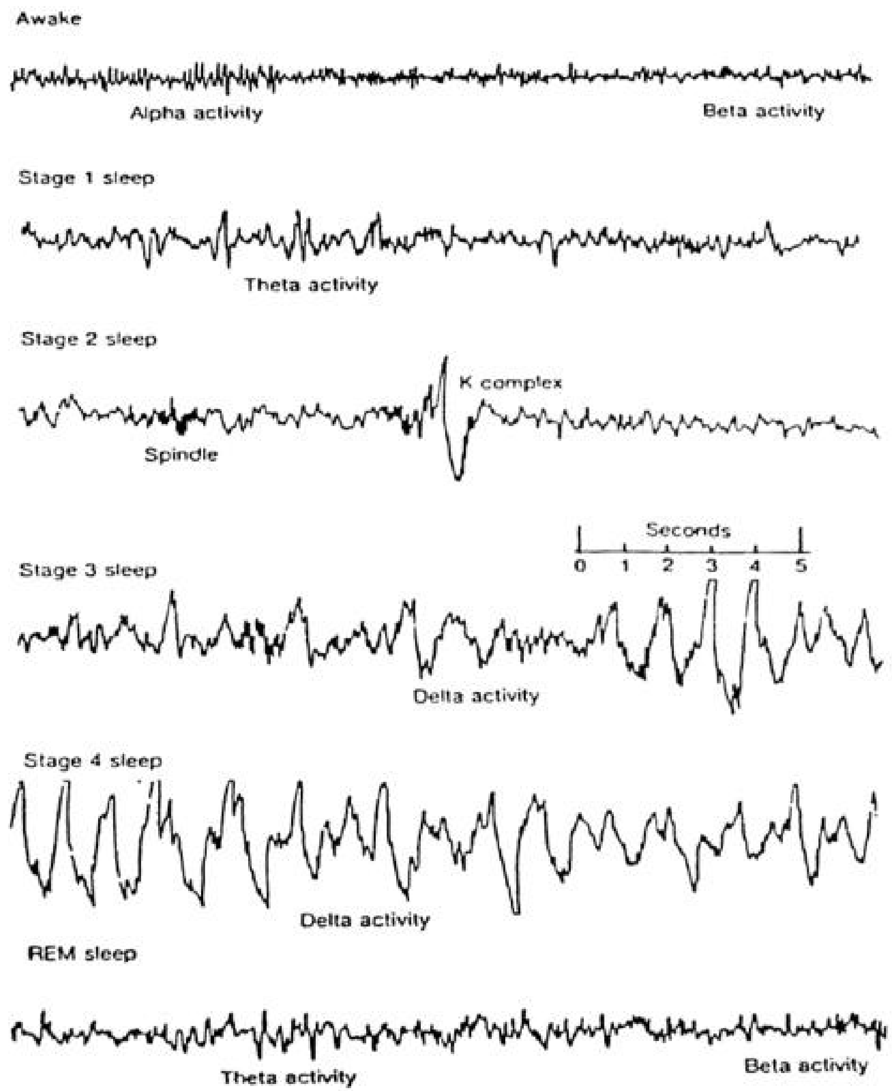
Sleep analysis

- Quality of life is heavily dependent on quality of *sleep.*
- Between 5 and 10% of the adult population suffers from some form of sleep disorder (insomnia, heavy snoring, Obstructive Sleep Apnoea (OSA), etc…)
- Such people may be referred to a "sleep clinic" by their GP where various signals, including four channels of EEG, the EOG and oxygen saturation, will be recorded throughout the night.
- The EEG and the other signals are printed out and reviewed by a trained sleep technician (requiring 2 to 5 hours for each record).

Sleep EEG

- The four channels of sleep EEG are analysed using a rule-based system which assigns consecutive 30-second segments to one of six stages (Wake, Stages 1 to 4, REM sleep).

EEG in different sleep stages



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Sleep EEG

- The four channels of sleep EEG are analysed using a rule-based system which assigns consecutive 30-second segments to one of six stages (Wake, Stages 1 to 4, REM sleep).
- For example, two rules for stage 3:
  - an EEG record in which at least 20% but not more than 50% of the epoch consists of waves of frequency 2 Hz or lower which have amplitudes greater than 75 μV peak to peak.
  - sleep spindles may or may not be present in stage 3.

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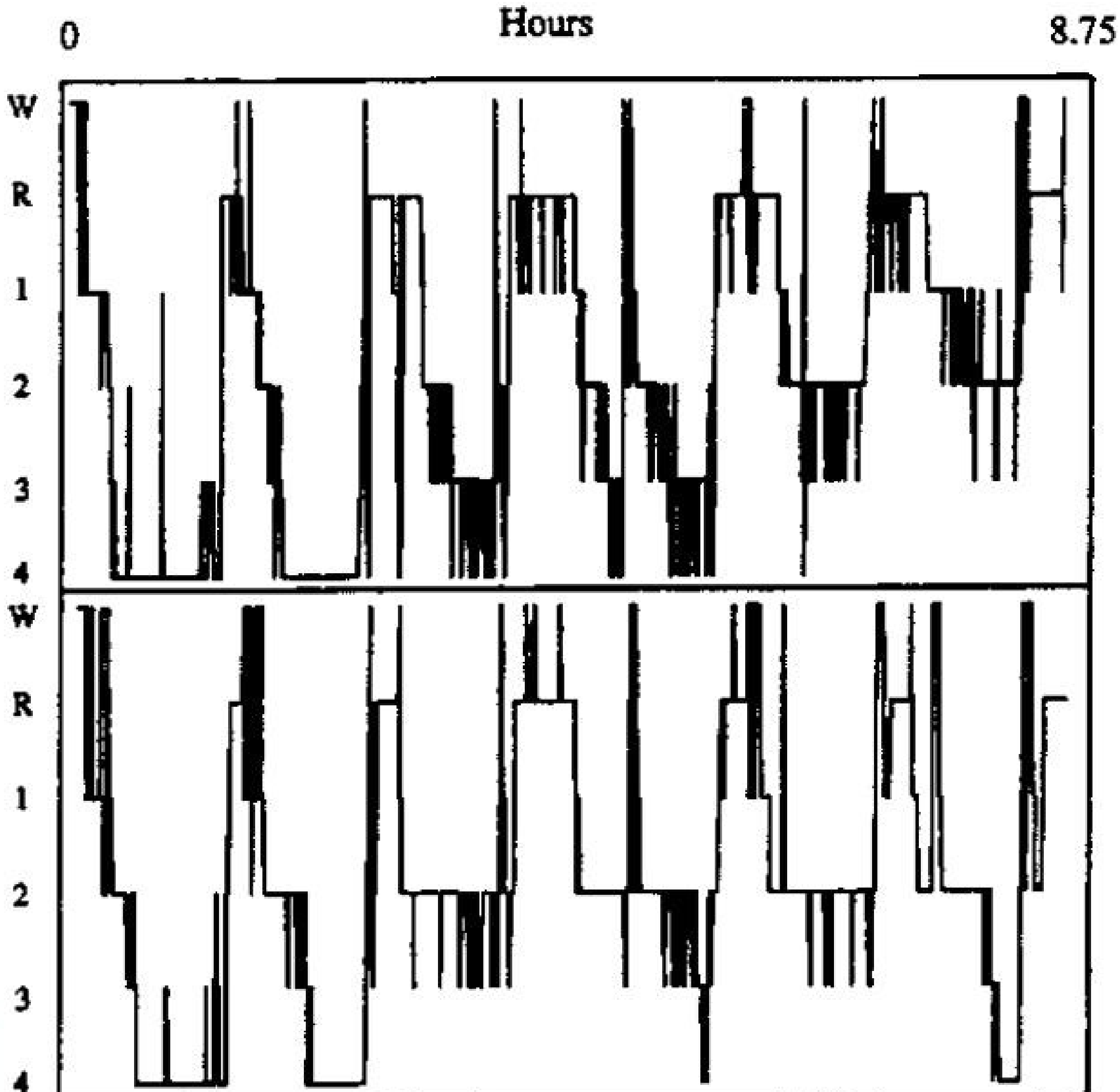
Conventional sleep scoring



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The sleep EEG
Automating the analysis

- The important information is in the *frequency* domain.

- Use the Short-term Fourier Transform or an Auto-Regressive (AR) model to extract the frequency-domain information.

AR models for spectral estimation

- The notation AR(*p*) refers to the autoregressive model of order *p*. The AR(*p*) model is written as follows:

$$X_t = \sum a_i X_{t-i} + \varepsilon_t \quad (1 \leq i \leq p)$$

where the a_i's are the ***parameters*** of the model and ε_t is a white-noise process with zero mean.

- An autoregressive model is essentially an infinite impulse response filter which shapes the white-noise input. The poles are the resonances of the filter and correspond to the spectral peaks in the signal.

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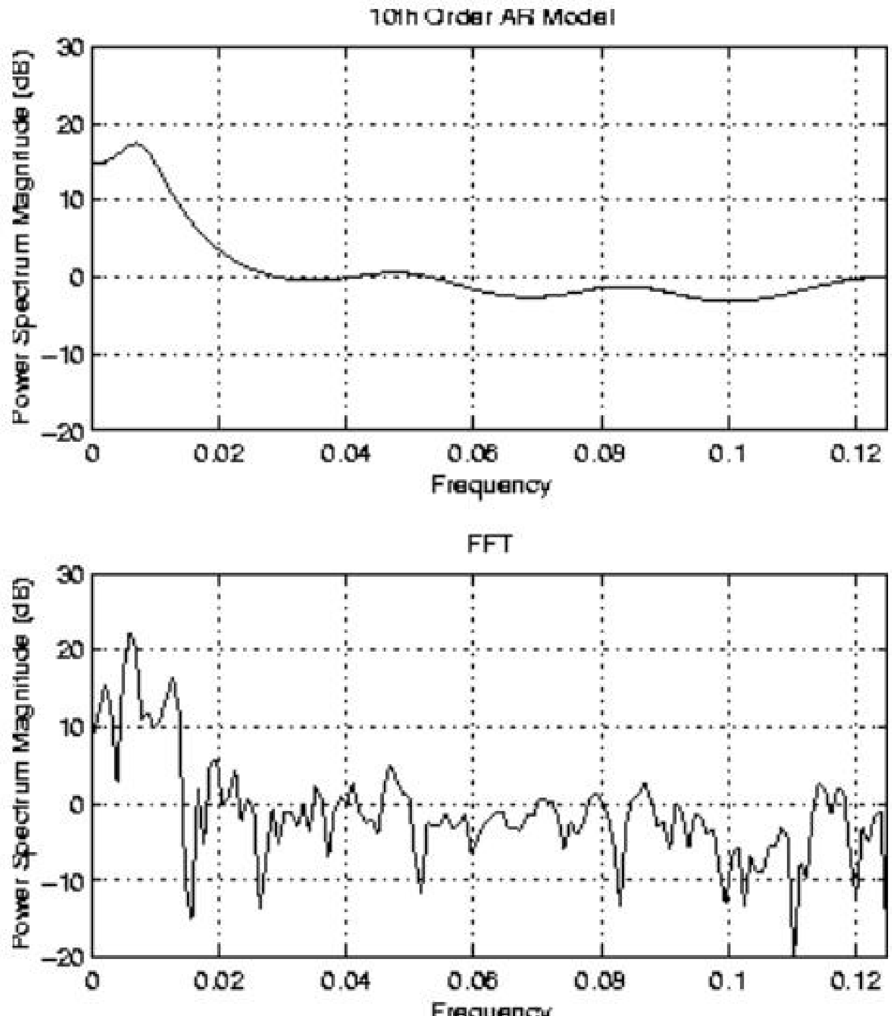
AR-model *vs* FFT spectra (EEG signal)



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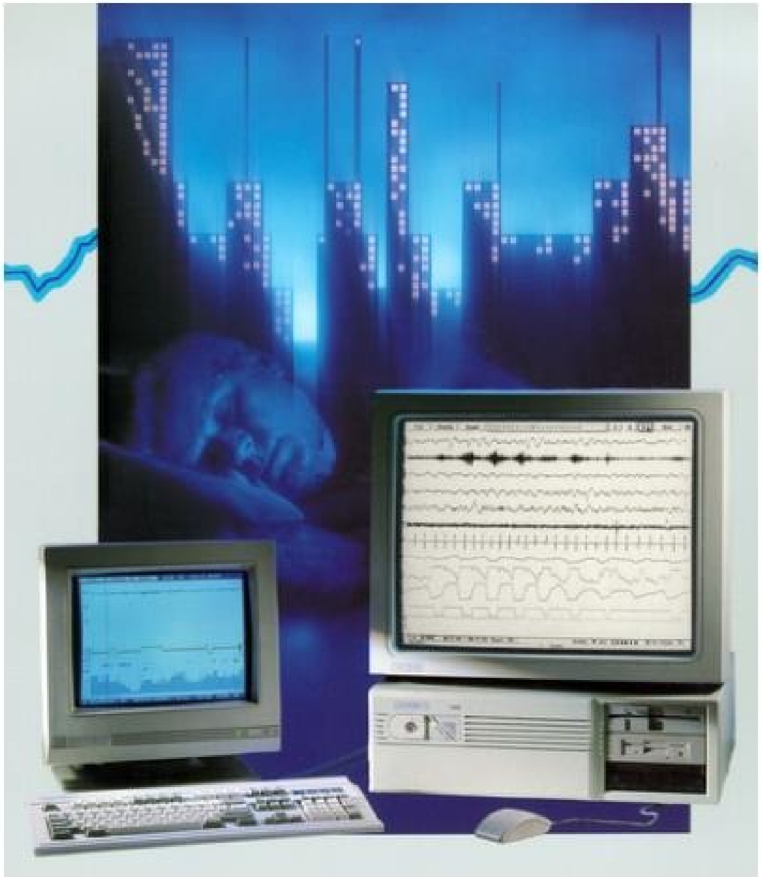
Sleep EEG analysis using neural networks



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Conventional vs neural computing

<u>Conventional computing</u>

- A set of programmed instructions
  - IF A = B THEN ADD 3 TO RESULT
    ELSE SUBTRACT 5

<u>Neural networks</u>

- The solution to a problem is *learnt* from a set of examples using error feedback

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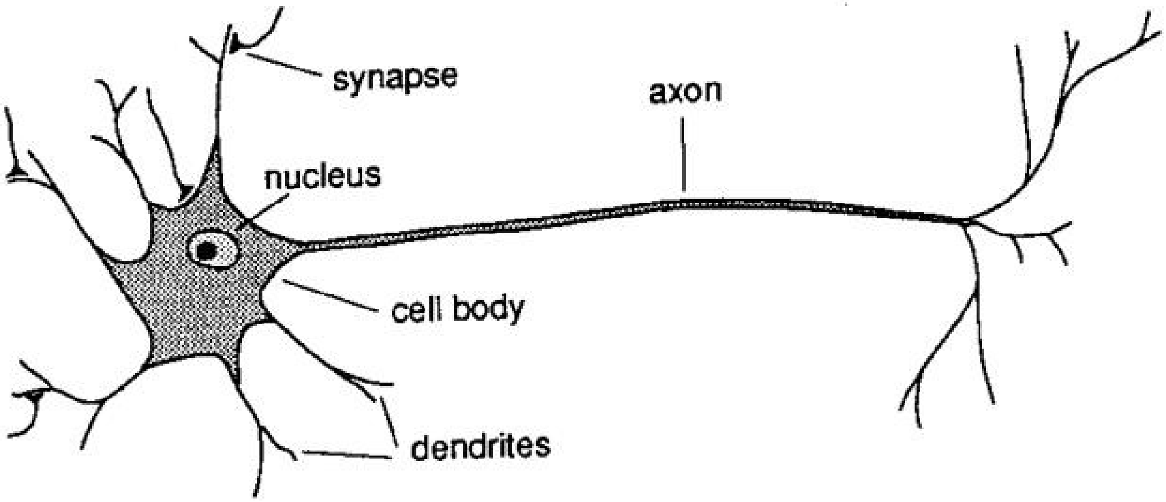
Neural networks



By analogy with the brain, *artificial* neural networks consist of large numbers of small units ("neurons") with modifiable connections ("synapses"), ordered in feedforward layers

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Some definitions

- Neural networks: A computational system which learns from examples how to recognise complex patterns in data, signals or images.
- Learning: The process of modifying the neural network's internal connections (the synaptic weights) until desired output responses are associated with the input patterns in the training set.
- Generalisation: The ability to generate the correct output response for a test pattern, an input pattern not previously seen (i.e. not in the training set).

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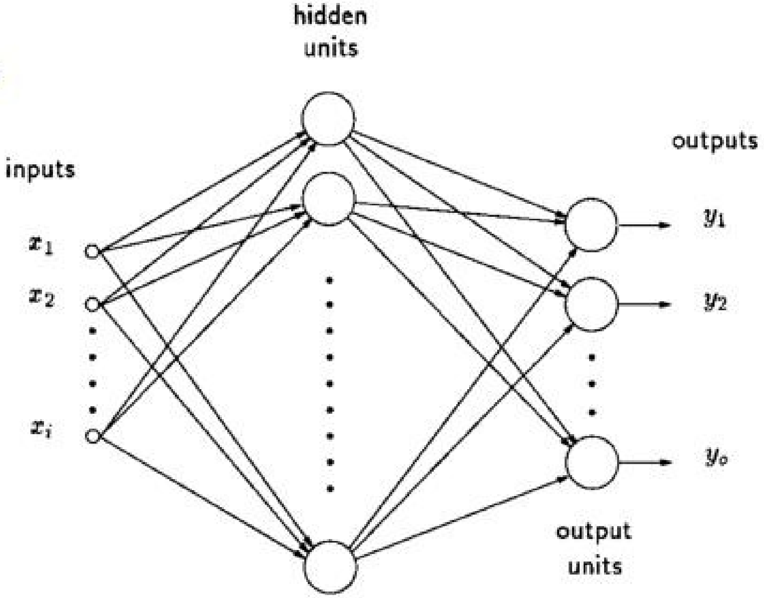
Sleep analysis using neural networks

- The signal recorded from one EEG channel is sampled at 128 Hz and segmented into one-second epochs.
- The input data are the ten AR coefficients for each consecutive one-second epoch.
- The multi-layer perceptron (MLP) neural network is *trained* to classify the input EEG data into three output classes: awake, light sleep or deep sleep. This involves the gradual modification of the synaptic weights in the hidden-output and input-hidden layers (error minimisation using gradient descent).

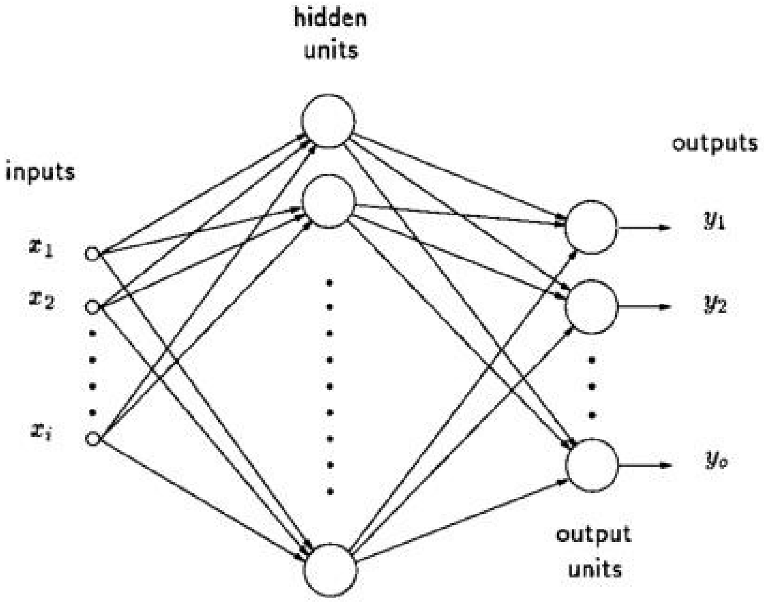


Sleep analysis using neural networks

- The *training* data are collected from human-scored sleep, selecting only "consensus-scored" Wake, REM or stage 1 and stage 4 data (independently scored by three experts).
- Once the network is trained, the intermediate stages for *test* EEG data are obtained by *interpolation*.

Sleep analysis using neural networks

- The neural network is *trained* to classify the input EEG data into three output classes: wakefulness, light sleep or deep sleep.
- The trained neural network is used for the automated analysis of the EEG recorded from new patients (*test* data).



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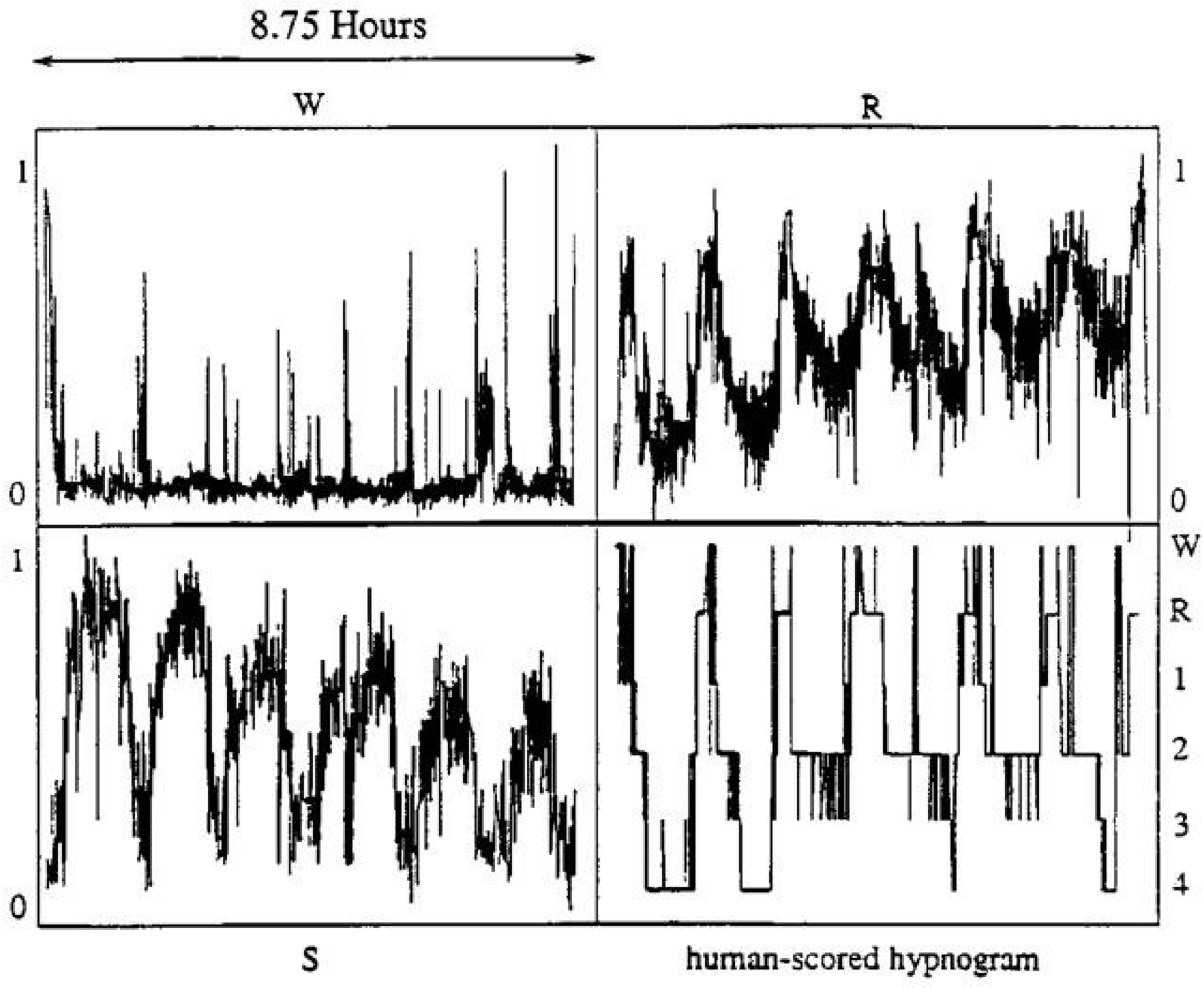
Sleep analysis using neural networks



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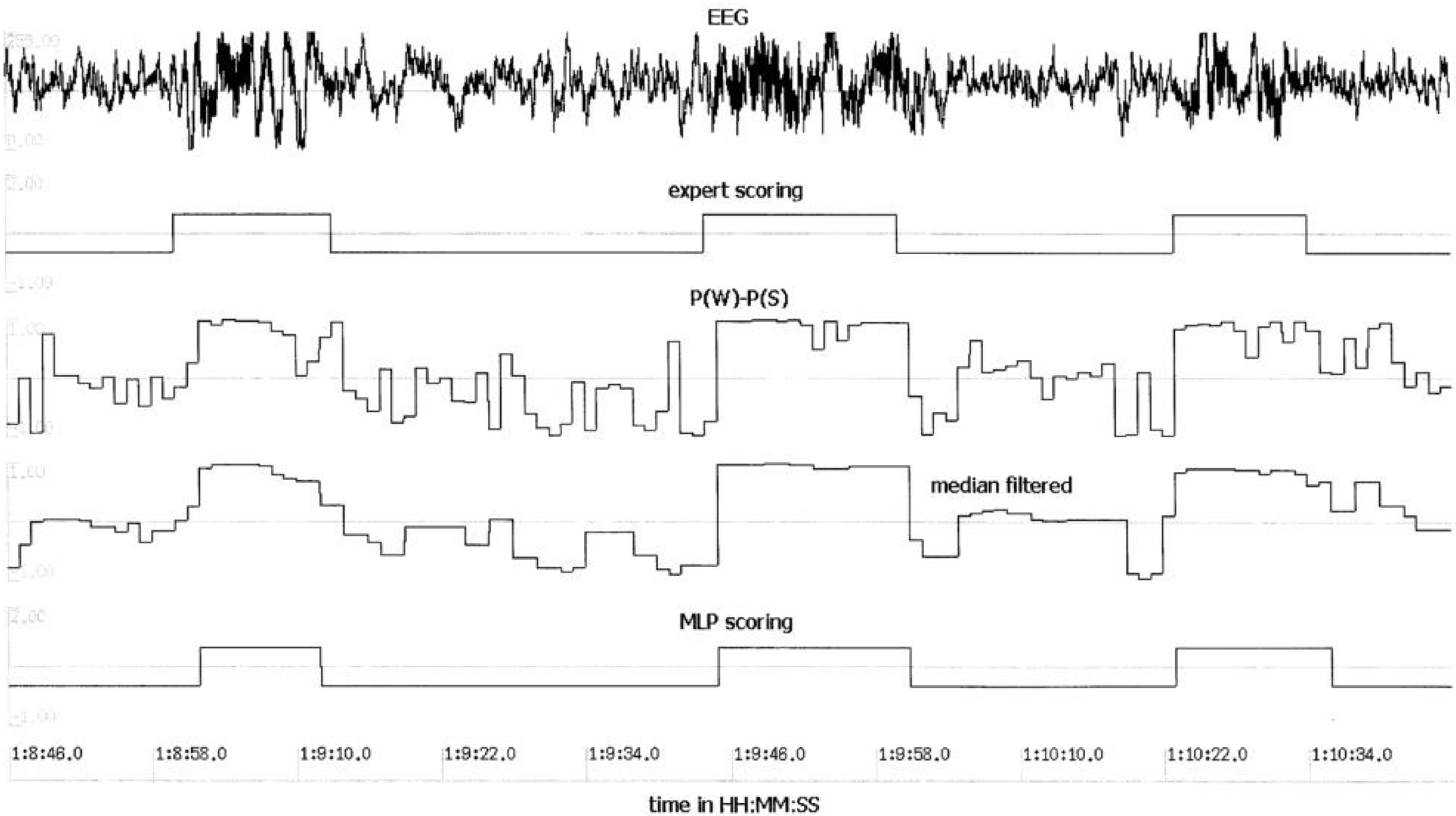
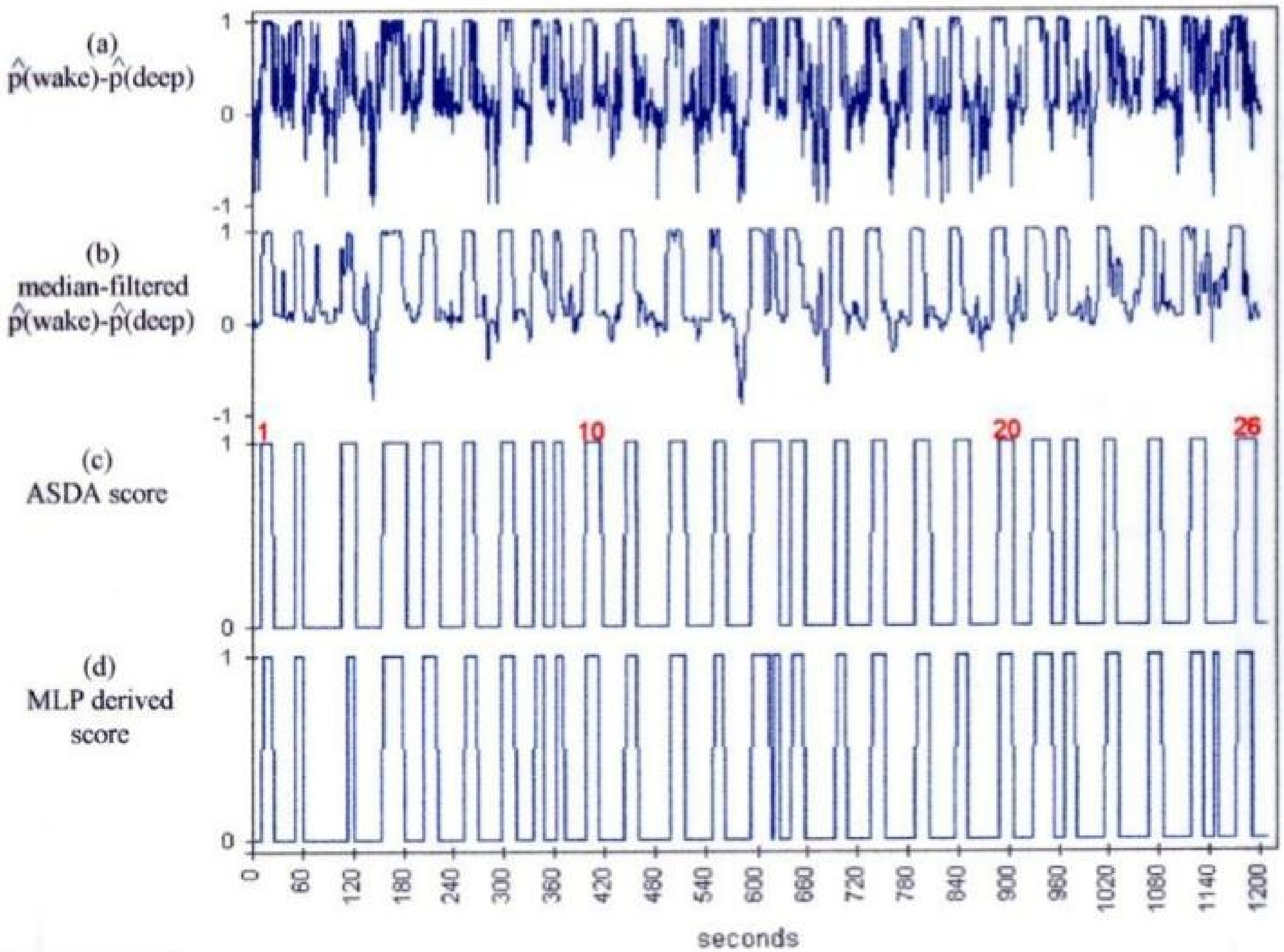
Study of arousals in OSA

- Seven 20-minute recordings from patients with different levels of OSA used as test data
- EEG scored by one expert according to the American Sleep Disorders Association (ASDA) rules
- P(Wake) - P(Deep Sleep) used to represent the sleep-wake continuum
- Transients shorter than 3 s discarded using median filtering

Sleep analysis using neural networks (2 mins of data)



Sleep analysis using neural networks (20 mins of data)



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Sleep analysis using neural networks

- Continuous tracking of sleep-wake continuum using single channel of EEG
- Events on a 2 to 5-second timescale are clearly detected
- This type of analysis is *not* possible with the traditional sleep scoring methods, which require several channels and only have 30-sec resolution
- Oxford Medical incorporated neural network analysis as an option within their Sleep Analysis software

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Sleep analysis using neural networks Oxford BioSignals' first product

- Continuous tracking of sleep-wake continuum from a single-channel of EEG
- Automated analysis makes it possible to quantify severity of OSA (and other sleep disorders) before and after treatment.

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OXFORD BioSignals