INTRODUCTION TO BIOMEDICAL SIGNAL AND IMAGE PROCESSING

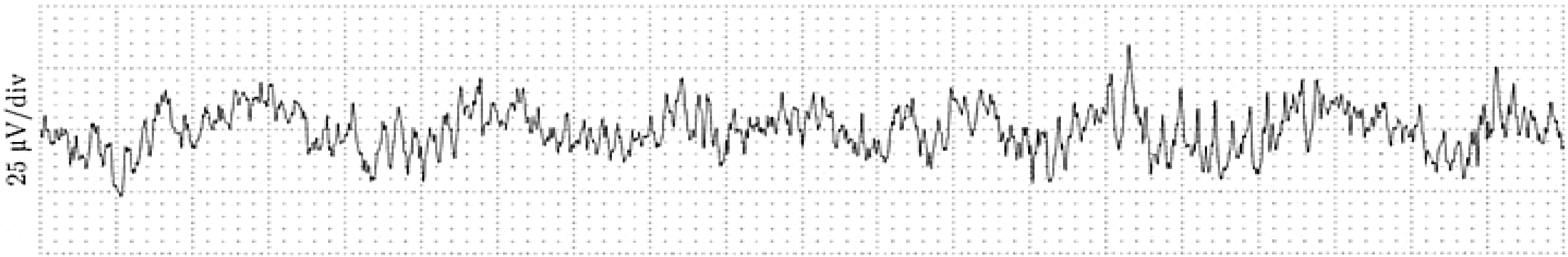
- Signals convey information
- Signals
- Multichannel signals
- Multidimensional signal
- Signal processing selectively eliminates information
- Stages in biomedical signal and image processing
- Examples of electroencephalogram (EEG), electrocardiogram (ECG) and electromyogram (EMG)
- Electrocardiogram with arrhythmias and myocardial ischaemia
- Electrocardiogram with myocardial ischaemia
- Electromyogram of a term and pre-term delivery
- Examples of electroencephalographic rhythms
- Example of computed tomography (CT) image

Signals convey information

- A signal is a function of one or several variables that carries useful information
- A signal is biological if it is recorded from a living system and conveys information about the state or behavior of that system
- One-dimensional signals depend on a single variable such as time
- Multichannel signals are simultaneous, taken from different points of a system and depend on a single variable such as time
- Multidimensional signals (images) depend on several variables such as spatial coordinates

Signals

- An electroencephalogram



- A segment of signal may be represented as a sum of several sinusoids of different amplitudes and frequencies:

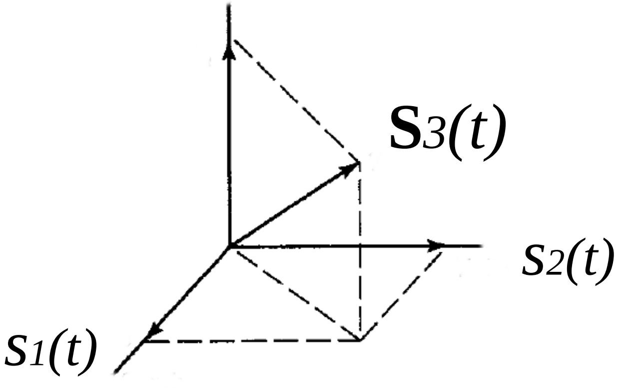
$$\sum_{i=1}^{N} A_i(t)\,\sin\left(2\pi F_i(t)\,t + \Theta_i(t)\right)$$

- where *{Ai(t)}*, *{Fi(t)}*, and *{Θi(t)}* are the sets of amplitudes, frequencies and phases

Multichannel signals

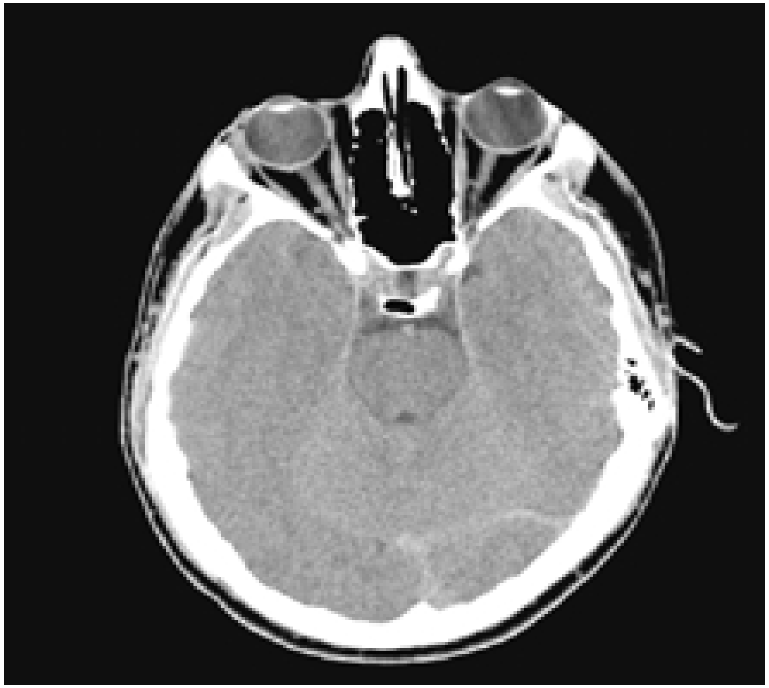
- Three-channel electrocardiogram

$$\mathbf{S}_3(t) = \begin{bmatrix} s_1(t) \\ s_2(t) \\ s_3(t) \end{bmatrix}$$



Multidimensional signals

- Multidimensional signals (images) *f(x, y)* depend on several variables such as spatial coordinates *(x, y)*



$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

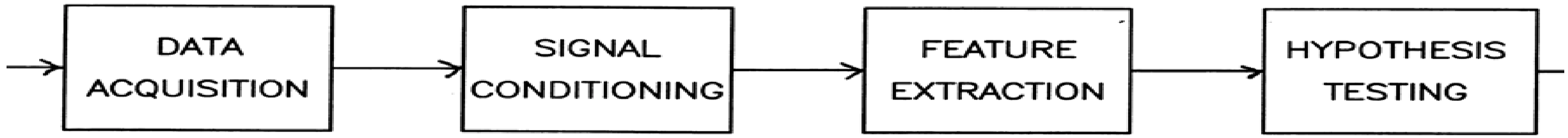
(Gonzales, Woods)

Signal processing selectively eliminates information

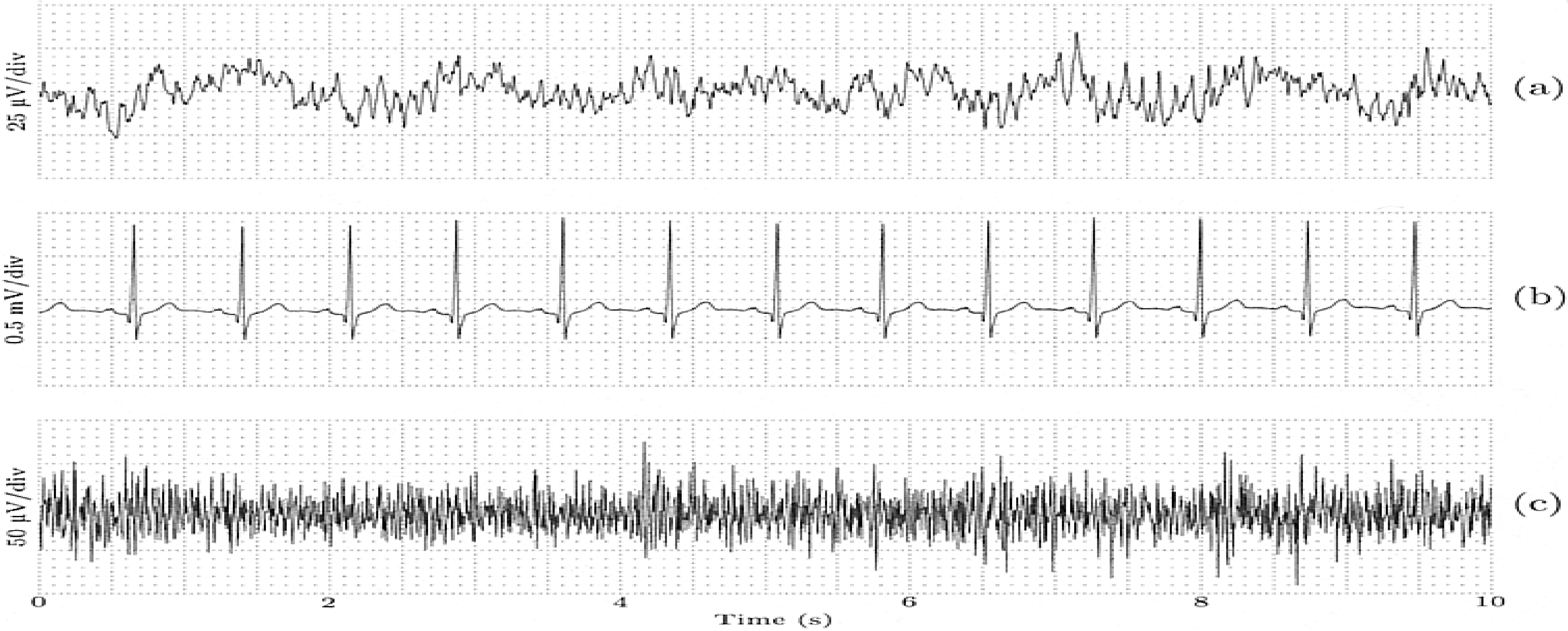
- A signal conveys the information of interest as well as irrelevant information (50/60 Hz power line interference, motion artifacts)
- What constitutes information of interest depends on the specific application (arrhythmia detection, transient ischaemia detection)
- The purpose of signal processing is to selectively eliminate irrelevant information from a signal to make the information of interest more easily accessible to a human observer or a computer system
- It is not possible to add information to a given signal, only to eliminate it

Stages in biomedical signal and image processing

- Data acquisition (to capture the signal and encode in a form suitable for computer processing, to avoid losing information about the signal)
- Signal conditioning (to eliminate extraneous components such as noise: general techniques, the same dimensionality of the signal)
- Feature extraction (identifying and measuring a small number of parameters or features that best characterize the information of interest: signal- and application-specific techniques, much lower dimensionality – e.g. KL coefficients, edge detection)
- Hypothesis testing, decision making (Clinical applications, what course of actions has to be taken? E.g.: Does a patient show a specific pathology in heart beats based on ECG? Does a patient have a tumor based on a brain scan?)

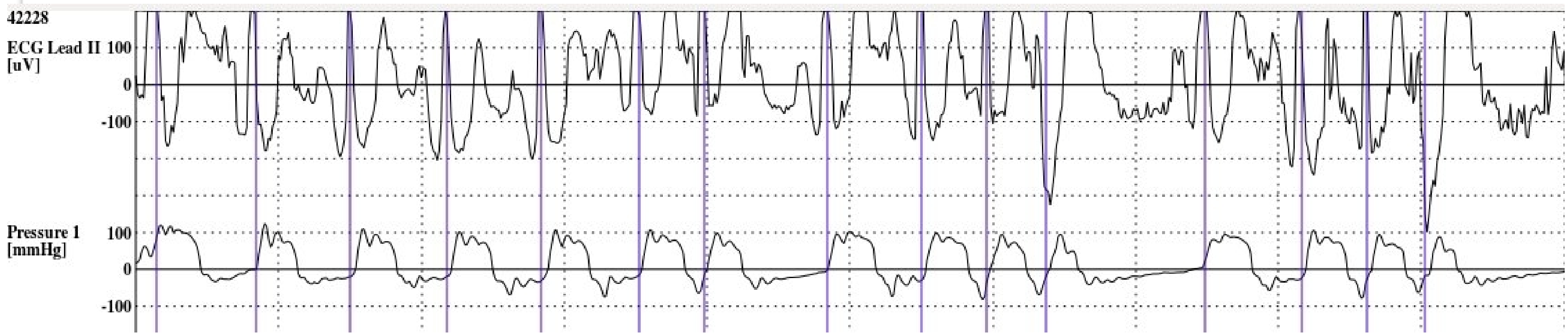


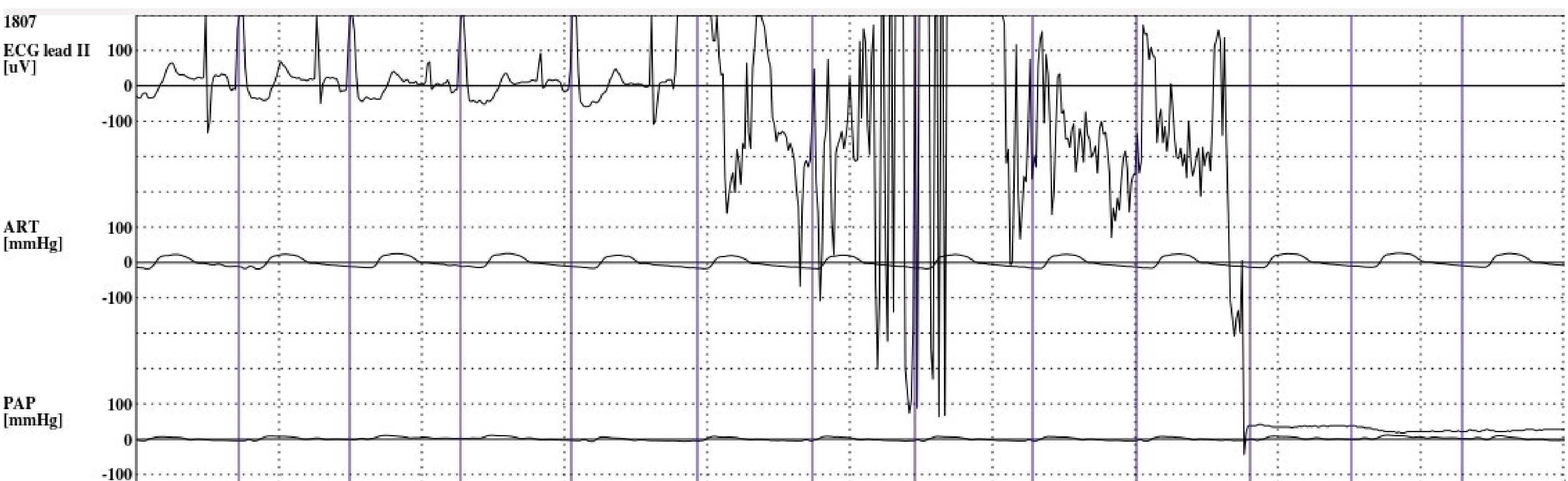
Examples of electroencephalogram (EEG), electrocardiogram (ECG) and electromyogram (EMG)



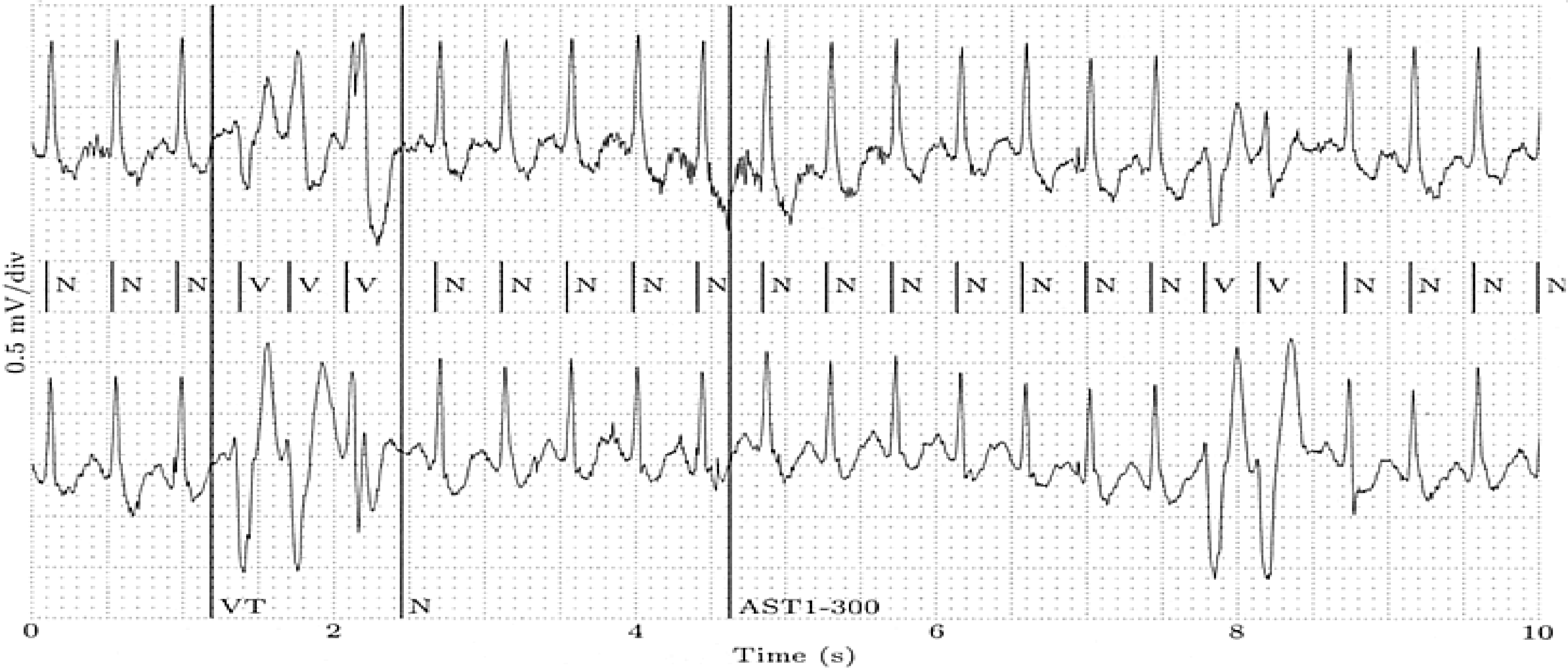
(Sornmo, Laguna)

Examples of electrocardiogram (ECG)





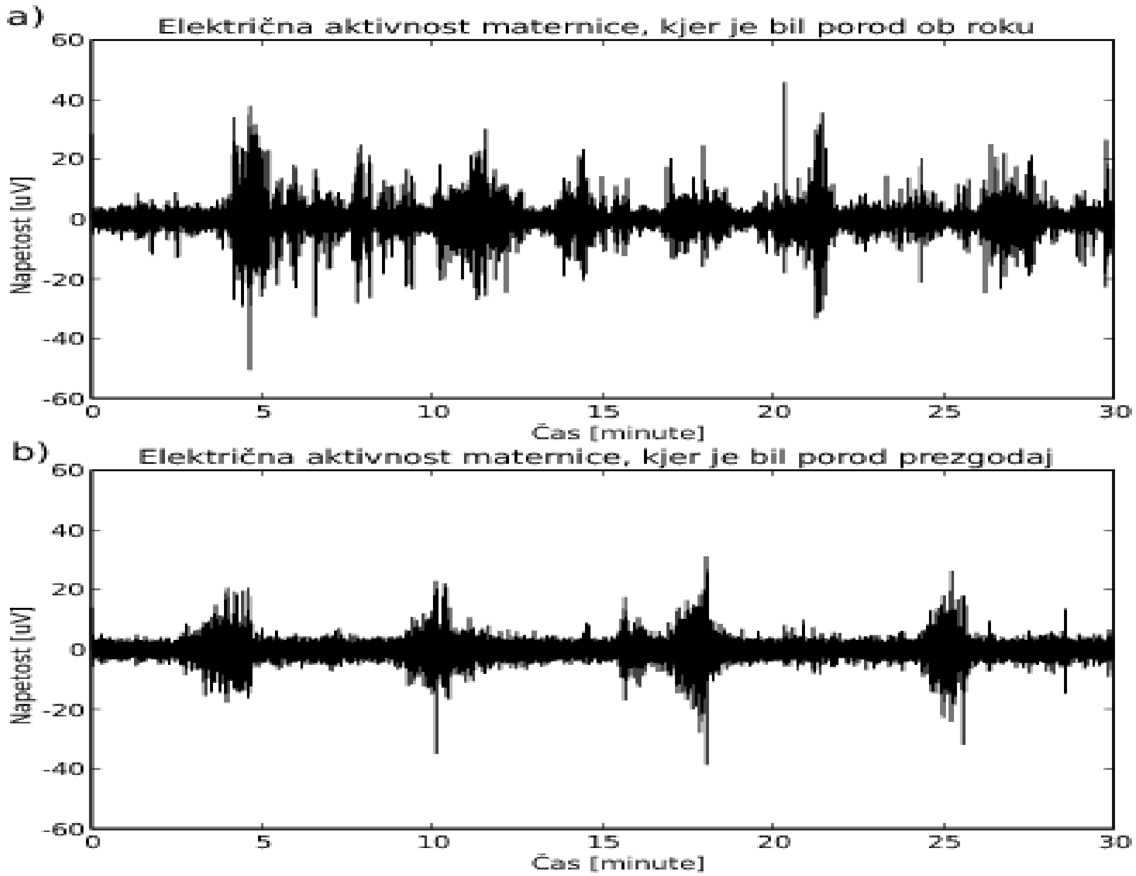
Electrocardiogram with arrhythmias and myocardial ischaemia



(Sornmo, Laguna)

Electrocardiogram with myocardial ischaemia

Electromyogram of a term and pre-term delivery



Examples of electroencephalographic rhythms

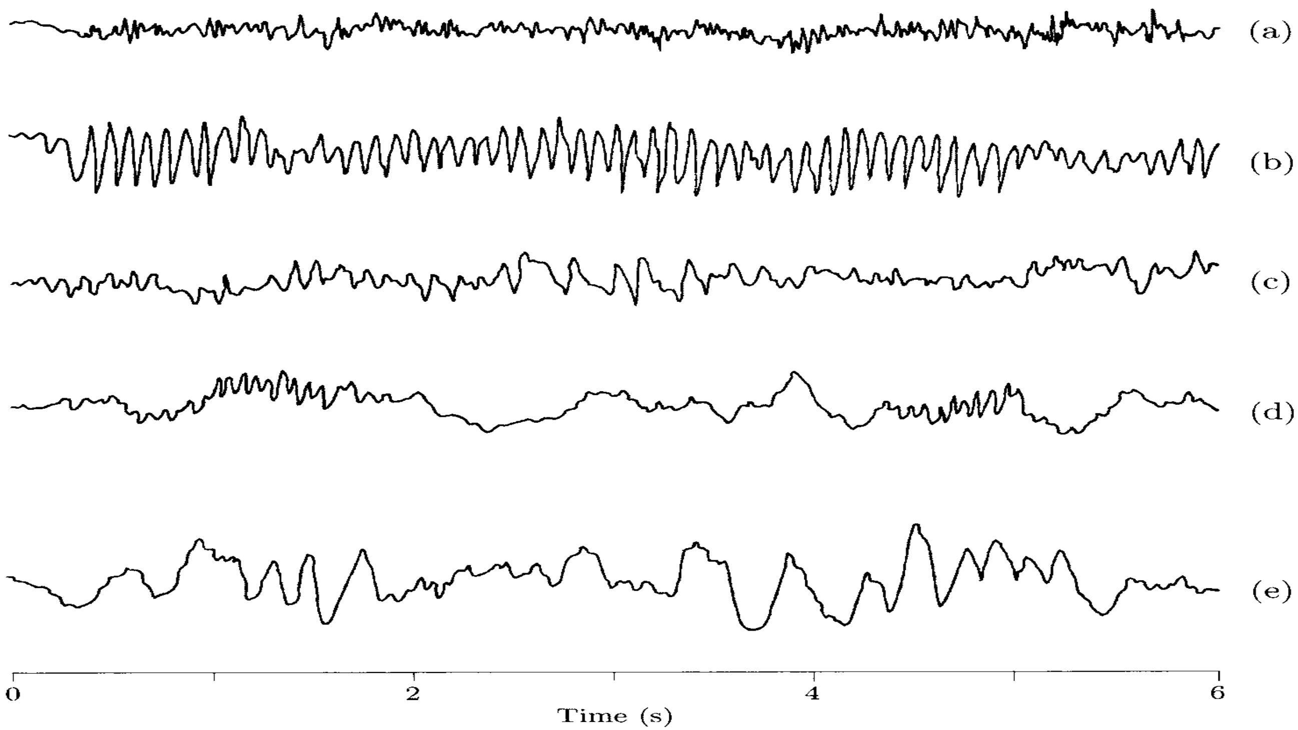


Figure 2.3: Electroencephalographic rhythms observed during various states from wakefulness to sleep: (a) excited, (b) relaxed, (c) drowsy, (d) asleep, and (e) deeply asleep. This example is classical and was originally presented by the famous EEG pioneer H.H. Jasper [12].

(Sornmo, Laguna)

Example of computed tomography (CT) image

(Suri, Wilson, Laxmanarayan, Handbook of Biomedical Image Analysis)

Example of computed tomography (CT) image

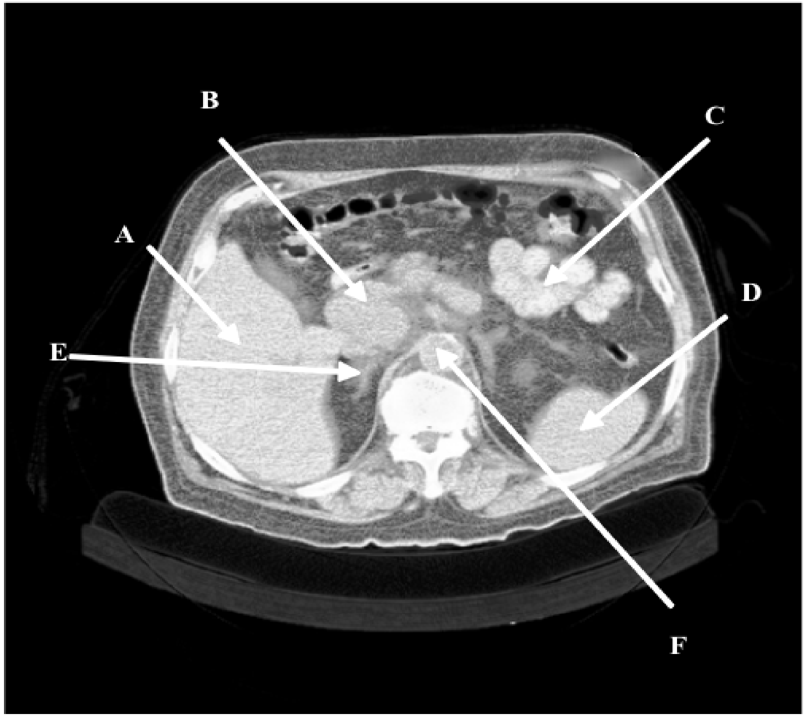


Figure 4.4: Contrast enhanced, helical CT scan through the abdomen and the head of the pancreas obtained with a reconstruction width of 8 mm (equal to slice thickness). A = liver; B = head of pancreas with tumor; C = bowel; D = spleen; E = right adrenal; F = aorta.

(Suri, Wilson, Laxmanarayan, Handbook of Biomedical Image Analysis)