# Introduction

***signal*** = every entity which contains some physical ***information***

**Examples:**

| Signal | | Information |
|---|---|---|
| Acoustic waves<br>Electric current given by a microphone | → | Music,<br>speech,<br>... |
| Light waves<br>Current given by a spectrometer | → | Light source (star, …)<br>... |
| Number series | → | Physical measurements |
| Photography | → | … |

# Typical Signals

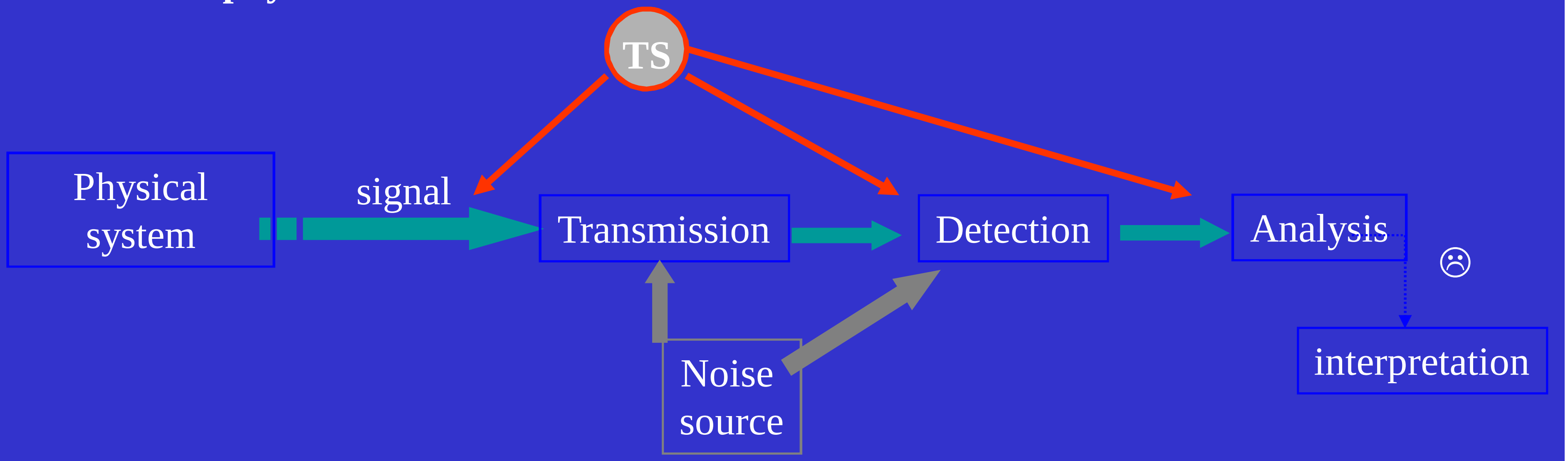
- Speech
- Biomedical
- Sound & Music
- Video & Image
- Radar
- Instrumentation/Control

***Signal processing*** = procedure used to:

- ⌧ extract the information (filtering, detection, estimation, spectral analysis...)
- ⌧ Adapt the signal (modulation, sampling….)
  (to transmit it or save it)
- ⌧ pattern recognition

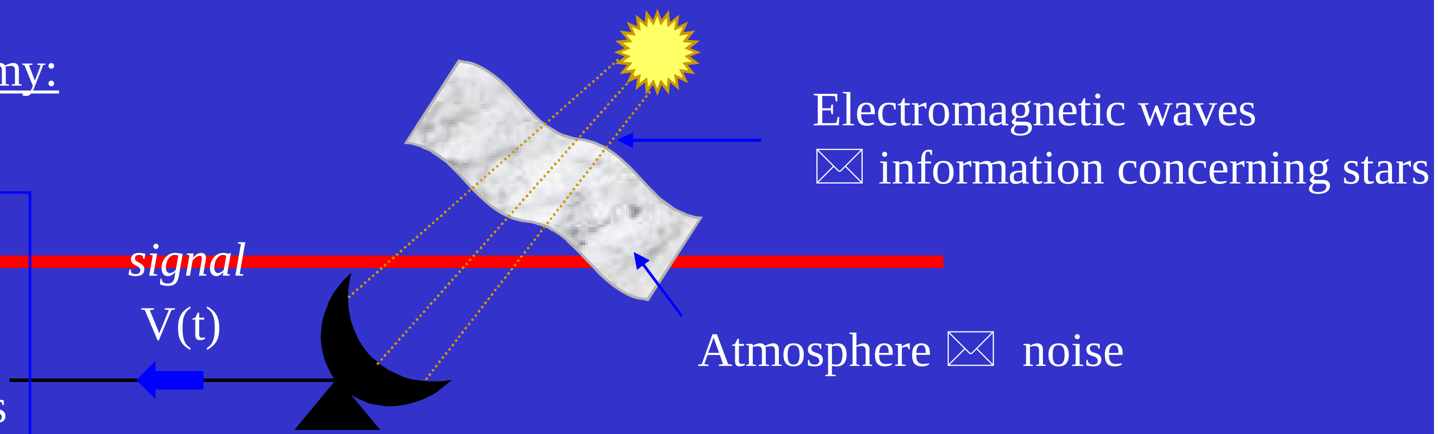
• • •

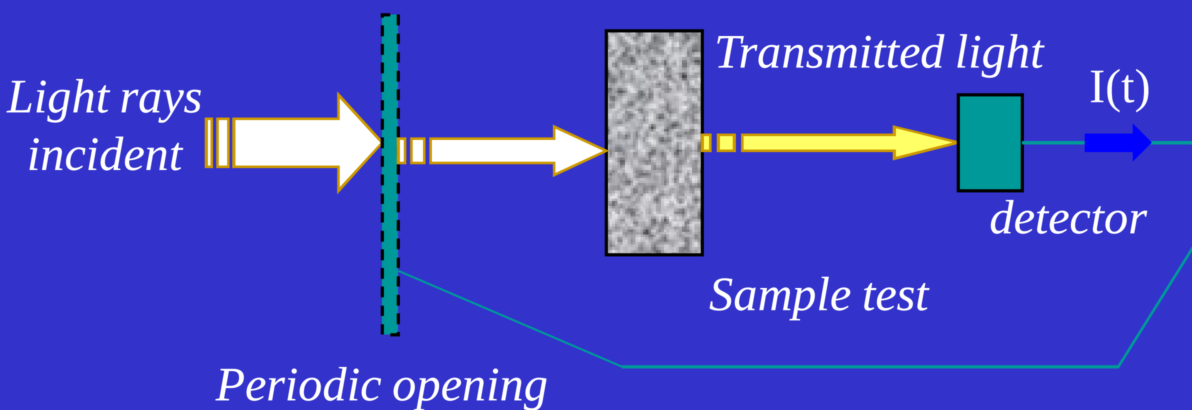
**In physics**:



**Exemples:** Astronomy:

**Sig. Process.:**
⌧ sampling
⌧ filtering
⌧ spectrale analysis
...




**Signal processing:**
⌧ Spectral analysis
⌧ Synchronous detection
...

## Classification of signals :

***Dimensional classification*** : ⟷ Number of free variables.

Examples :

Electrical potential V(t) = Unidimensional signal

Statistic image black and white ⇔ brightness *B(x,y) = bi-dimensional* signal
Black and white film ⇔ *B(x,y,t) = tri-dimensional signal*
...

⌧ The signal theory is independent on the physic phenomenon and the types of variables.

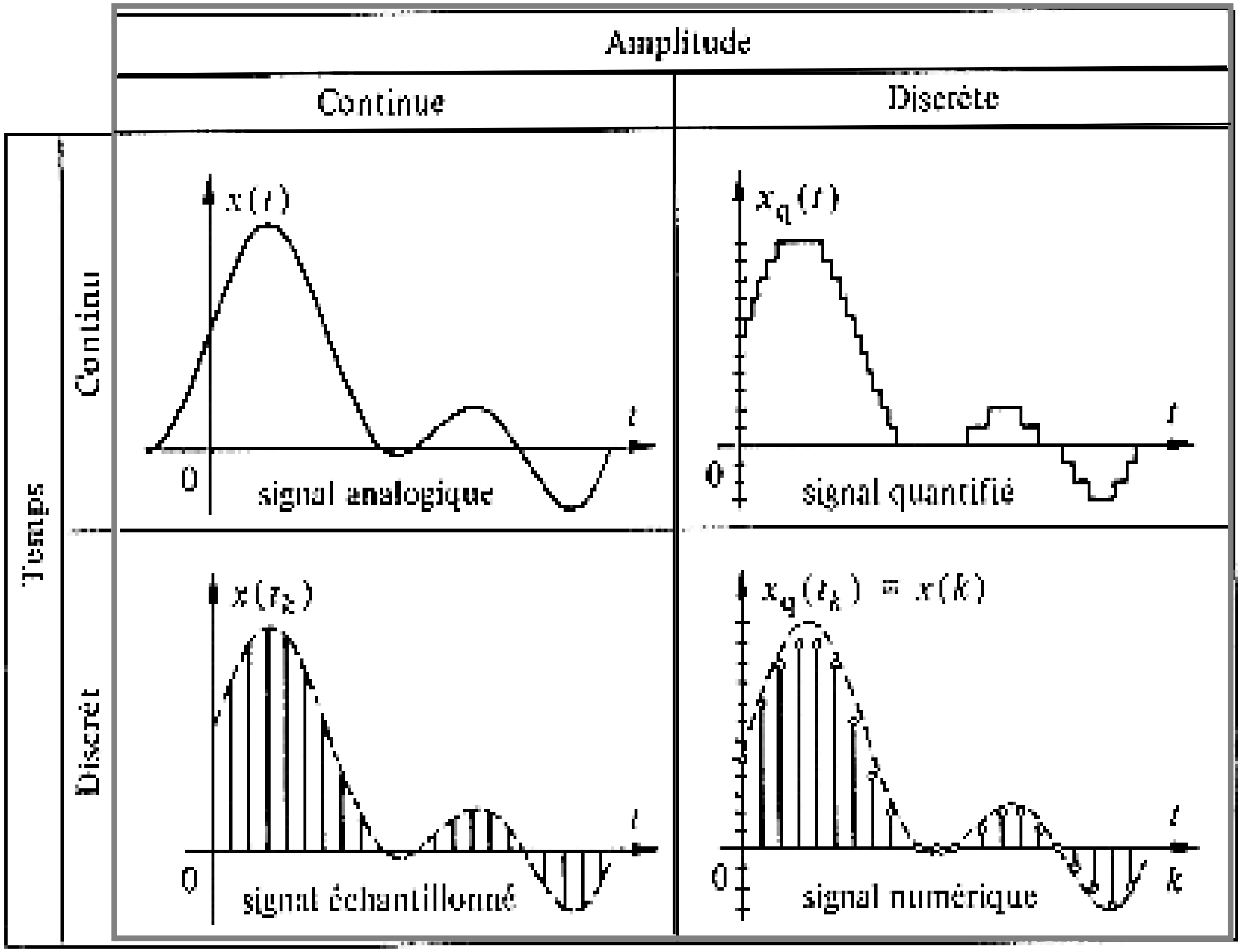
***Phenomenological Classification*** ⟷ Random or deterministic evolution

Deterministic signal : temporal evolution can be predicted or modeled by an appropriate mathematical mode

Random signal : the signal cannot be predicted ⇒ *statistical description*

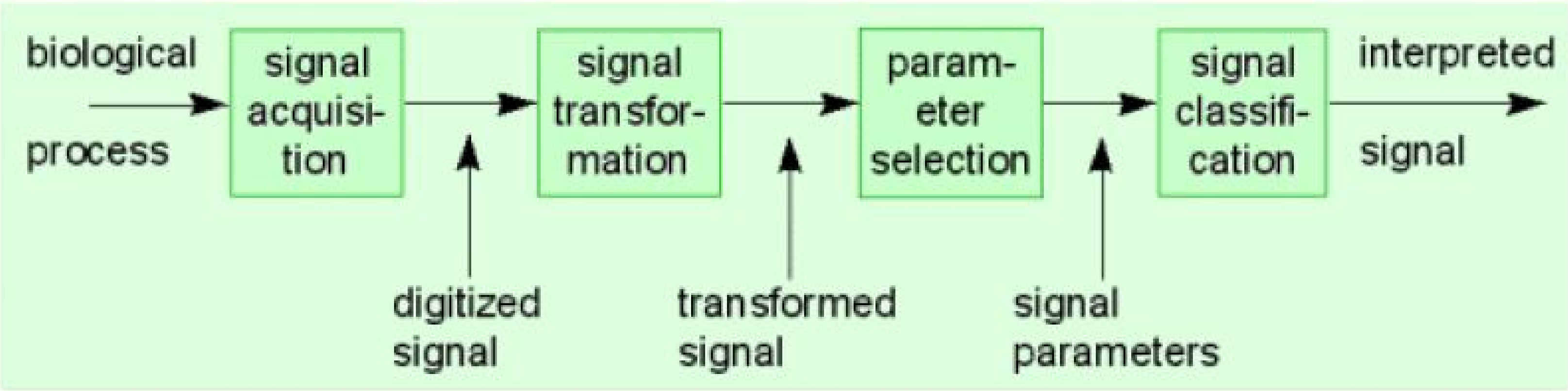
⌧ Every signal has a random component
(external perturbation, …)

***Morphological classification:***

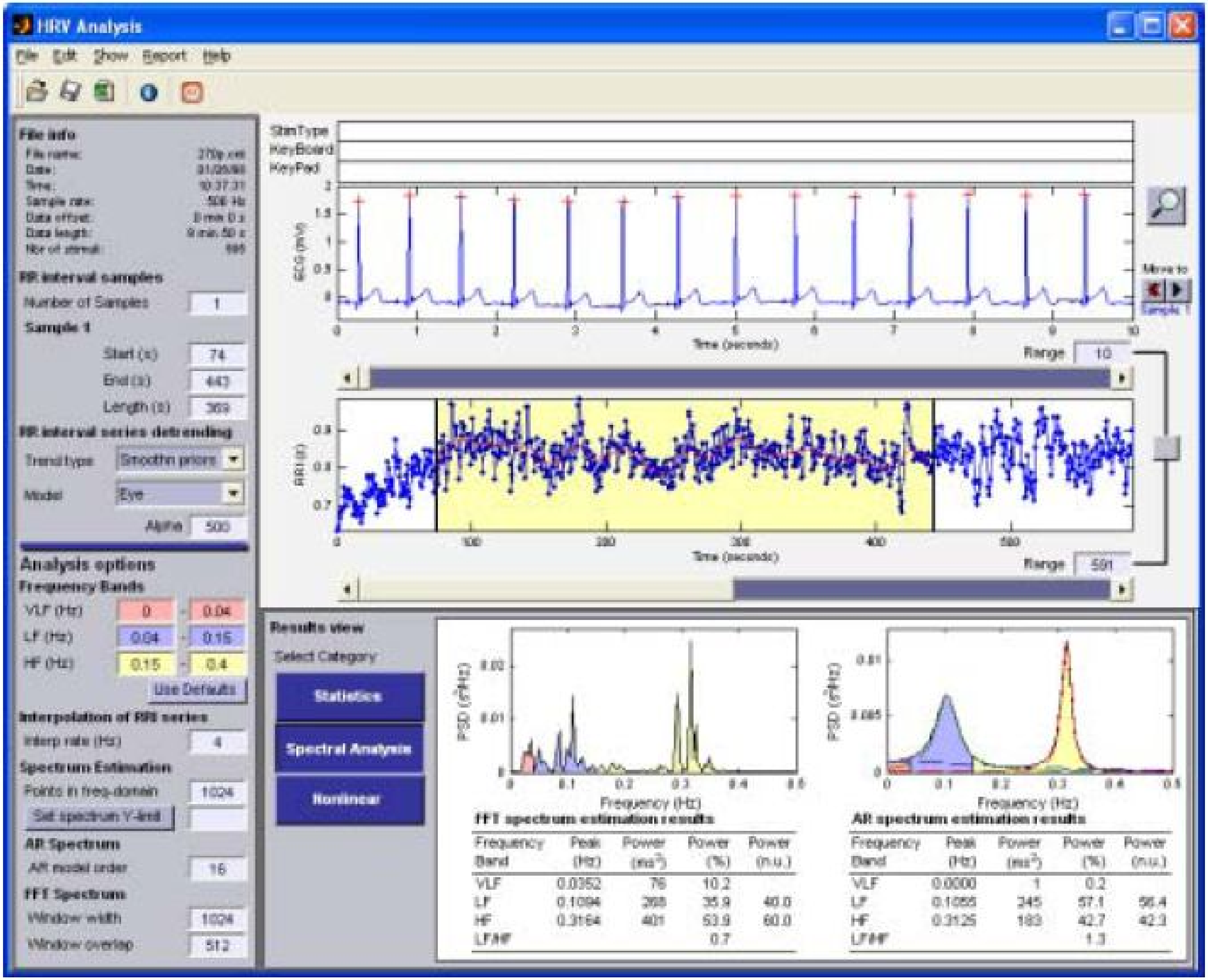



[Fig.2.10,(I)]

# Signal processing system



# HRV analysis



# Probability

- In many practical situations of interest (games of chance, digital communications, etc..), it has been observed that when a random experiment is repeated a large number of times, the sequence of results so obtained shows a high degree of regularity, or predictability.

- Let us be more specific: suppose we repeat a random experiment (e.g. rolling a die) $n$ times. Let $\eta(A, n)$ be the number of times that a certain event $A$ occur (e.g. the result is even). It has been observed that

$$\frac{\eta(A,n)}{n} \longrightarrow \text{constant} \quad \text{as} \quad n \longrightarrow \infty \qquad P(A) = \lim_{n\to\infty} \frac{\eta(A,n)}{n} \tag{1}$$

- The ratio $\eta(A, n)/n$ is called the relative frequency.

- The constant provides a quantitative measure of the likelihood of $A$.

# Probability

If two events A and B occurs,

$$P(A,B) = \lim_{N\to\infty} \frac{n_{AB}}{N} =$$

$$\lim_{N\to+\infty}\left(\frac{n_{AB}}{n_A}\frac{n_A}{N}\right) = \lim_{N\to+\infty}\left(\frac{n_{AB}}{n_A}\right)\cdot \lim_{N\to+\infty}\left(\frac{n_A}{N}\right) \overset{déf}{=} P(B/A)\cdot P(A)$$

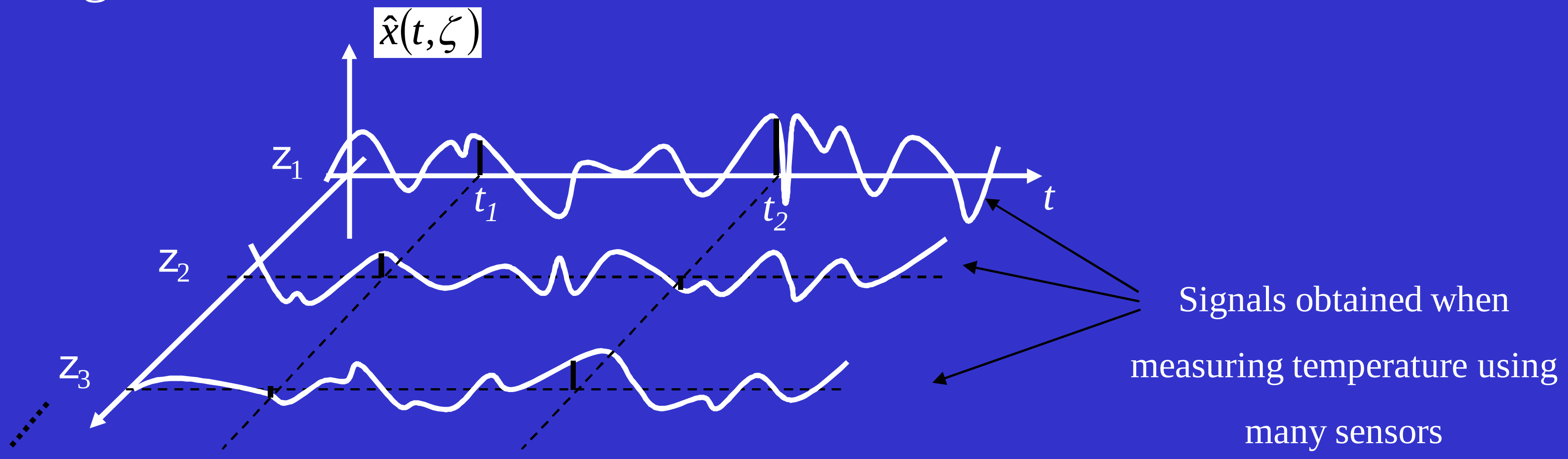
P(B/A) is the conditional probability

$$P(A,B) = P(B/A)\cdot P(A) = P(A/B)\cdot P(B)$$

If A and B are independent, $P(A,B)=P(A).P(B)$

# Random variable and random process

- Let us consider the random process : measure the temperature in a room
- Many measurements can be taken simultaneously using different sensors (same sensors, same environments…) and give different signals



# Random variable and random process

- The random process is represented as a function $\hat{x}(t,\zeta)$
- Each signal *x(t)*, for each sensor, is a random signal.
- At an instant t, all values at this time define a random variable