PROCESSAMENTO DE SINAL E IMAGEM EM FÍSICA MÉDICA

2019/2020 – 2º Semestre (F4012)

Introduction to Digital Signal Processing

Introdução ao Processamento Digital de Sinal

What is Digital Signal Processing?

“The process whereby real world phenomena can be translated into digital data for analysis, manipulation and synthesis.”

“This is done by sampling a signal with na instrument, like a camera or a microfone, which in turn generates a sequence of numbers.”

A signal carries information (useful information + noise).

The goal of signal processing is to **Extract, enhance or rearrange the useful information carried by the signal.**

Some examples of typical signals are presented in the following slides

Examples of Typical Signals

Electrocardiograph (ECG) Eletrocardiograma

The signal represents the electrical activity of the heart

The ECG is a periodic waveform.

1 period of the waveform represents 1 cycle of the blood transfer process from the heart to the arteries.

Examples of Typical Signals

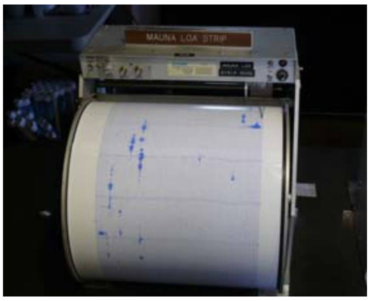
Electroencephalogram (EEG) Eletroencefalograma

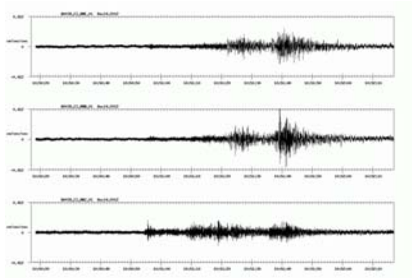
The signal represents the electrical activity caused by the random firing of neurons in the brain.

Examples of Typical Signals

Sismograph record Registo sismográfico

The signal represents the movement of the platform (ground) due to na earthquake, explotion or volcanic activity.

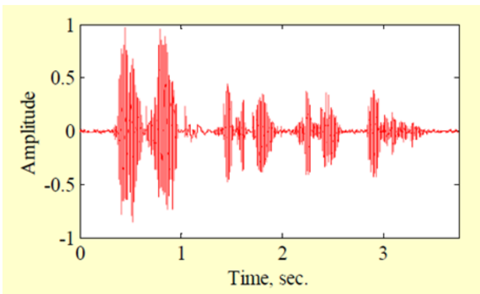




Examples of Typical Signals

Speech and music signals

The signal represents air pressure intensity as a function of time, at a fixed point in space.



The figure shows the waveform of the speech signal

“I like digital signal processing”.

Types of Signals

The way the signal is generated:

- Natural
- Synthetic

The number of independent variables:

- One-dimensional
- M-Dimensional

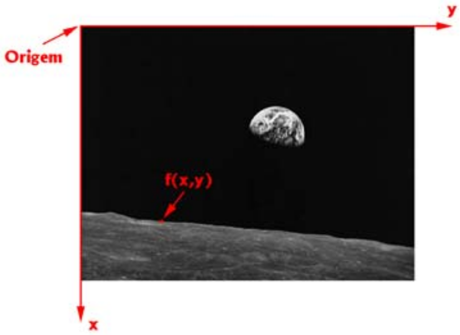
The number of independent sources:

- Single source (scalar signal)
- Multiple sources (vector or multi-channel signal)

Example of a two-dimensional (2D) signal

A greyscale ("black-and-white") image, represents light intensity as a function of 2 independent variables, the spatial coordinates x and y.

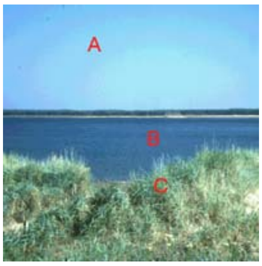
The intensity (greylevel) at location (x,y) can be expressed as f(x,y).



A digital image is a 2D discrete-time signal, and its 2 independent variables are discrete spatial variables.

Example of a multi-channel signal

A colour image is usually a vector signal composed of 3 signals, representing the 3 primary colours (red, green and blue).

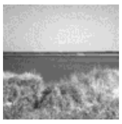


r(x,y)

g(x,y)

b(x,y)

Red (r)



Green (g)

Blue (b)

Example of a three-dimensional (3D) signal

An image is represented by a 2D matrix

f(x,y)

A video can de represented by a 3D matrix

f(x,y,t) 3rd Dimension – time (t)

Types of Signals

The methods used for information extraction in DSP depend on the types of signals and the nature of the information.

Besides being
- Natural / Synthetic
- One-dimensional / M-Dimensional
- Single / Multiple sources

The signal (real-valued or complex-valued) can be:

- Continuos
- Discrete

function of the independent variables.

and:

- Deterministic (can be uniquely described by a mathematical expression or look-up table)
- Stochastic (non-deterministic, has a random component).

Continuos / Discrete signals

For a 1D signal, the independent variable is usually labeled as time.

If the independent variable is

- continuous, the signal is called **continuous-time** signal
- discrete, the signal is called **discrete-time** signal

A continuous-time signal is defined at every instant of time.

A discrete-time signal is defined at discrete instants of time, thus it is a **sequence of numbers.**

Continuos / Discrete signals

A continuous-time signal with a continuous amplitude is usually called an **analog signal** (sinal analógico).

A discrete-time signal with discrete-values amplitudes represented by a finite number of digits is referred to as a **digital signal**.

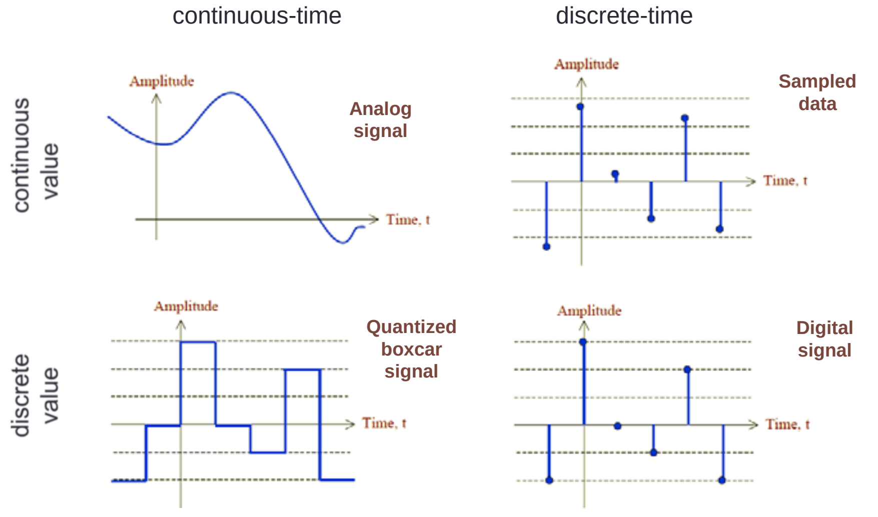
Digitized music (in a CD, mp4 file, etc.) is an example of digital signal.

A discrete-time signal with continuous-valued amplitudes is called a **sampled-data signal**.

A digital signal is thus a quantized sampled-data signal.

A continuous-time signal with a discrete-value amplitudes is usually called a **quantized boxcar signal**.

Continuos / Discrete signals



Continuos / Discrete signals

The functional dependence of a signal in its mathematical representation is often explicitly shown.

For a continuous-time 1D signal, the continuous independent variable is usually denoted by t. For example u(t).

For a discrete-time 1D signal, the discrete independent variable is usually denoted by n. For example v[n].

Each member of v[n] is called a **sample** (amostra).

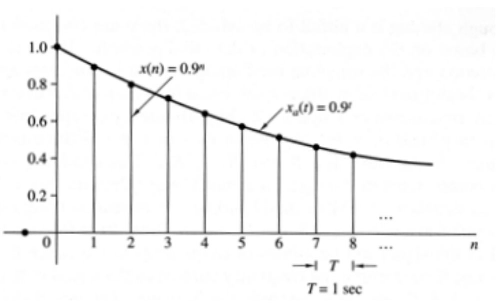
Often a discrete-time signal is generated by **sampling** a continuous-time signal at uniform intervals of time.

The independent discrete variable n can be normalized to assume integer values.

Quantization of an analog signal

Consider a continuous-time signal with a continuous amplitude (analog signal), given by

$$x_a(t)=0.9^t$$



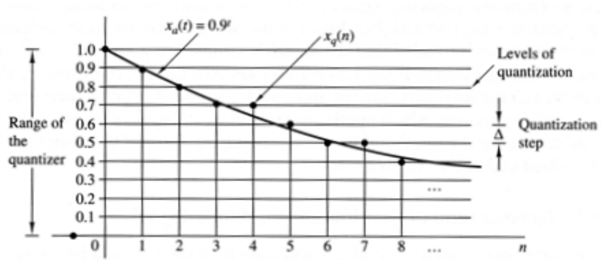
This signal is sampled at 1s intervals, resulting in

$x(n)=0.9^n$

where n is a discrete variable of time.

Quantization of an analog signal

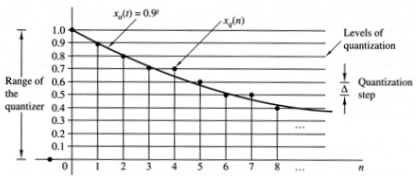
The amplitude of the signal is also quantized, with a quantization step (Δ):



The quantization error $e_q(n)$ is limited by Δ: $-\frac{\Delta}{2} \leq e_q(n) \leq \frac{\Delta}{2}$

Quantization of an analog signal

A digital signal x(n) is obtained, which is a simplified representation of the original analog signal $x_a(t)$



n	x(n)	Truncation	Rounding	$e_q(n)$ Rounding
0	1	1.0	1.0	0.0
1	0.9	0.9	0.9	0.0
2	0.81	0.8	0.8	-0.01
3	0.729	0.7	0.7	-0.029
4	0.6561	0.6	0.7	0.0439
5	0.59049	0.5	0.6	0.00951
6	0.531441	0.5	0.5	-0.031441
7	0.4782969	0.4	0.5	0.0217031
8	0.43046721	0.4	0.4	-0.03046721
9	0.387420489	0.3	0.4	0.012579511

Digital vs. Analog Signal Processing

- Conventional signal processing:

- Digital SP system:

[Source: Dan Ellis, 2010]

Digital vs. Analog Signal Processing

Pros (of DSP)

- Noise is easy to control after initial quantization
- Stability/duplicability
- Flexibility (parameters can easily be varied in software)
- Data storage without loss of signal fidelity
- Lower costs (in many cases)
- Easy to operate in the frequency-domain

Cons (of DSP)

- Limitations of A/D & D/A conversion
- Discrete-time processing artifacts (aliasing)
- Processing speed, due to A/D & D/A conversion
- Baseline complexity / power consumption