Computer Engineering Department - Digital Signal Processing

Lecture One (2020-2021)

Introduction to Digital Signal Processing (DSP)

Basic concepts of DSP

Digital Signal Processing (DSP) is an area of science and engineering that is applied in different fields. It is concerned with the numerical manipulations of signals and data in sampled form. It is applied in various applications such as noise filtering, speech and audio enhancement, biomedical signal processing, oil exploration, detection of nuclear explosions, and image processing. DSP provides another way to process the analog signals efficiently and easily.

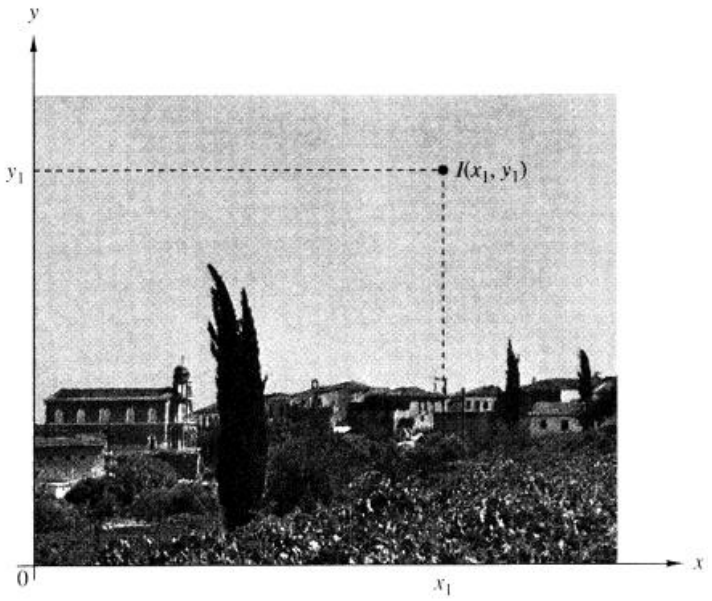
The scientific definition of Digital Signal Processing:

Digital: the word "digital" has different meaning based on the area of interest. For example, if the talking is about signals or data, the word digital represents as series of the digits 0 and 1 for the values of a physical quantity such as voltage. If the talking is about the digital system, this means systems with discrete inputs that produces outputs in the form of numbers.

Signal: is a function that carry information from one point to another point. It can be described by a function of one or more independent variable. The value of the function (i.e., the dependent variable) can be a real- valued scalar quantity, a complex-valued quantity, or perhaps a vector.

- Signals can have one independent variable such as audio, or two independent variable such as the image or three variable such as the video. In general, if the signal is a function of a single independent variable, the signal is called a **one-dimensional signal**. On the other hand, a signal is called ***M*-dimensional**

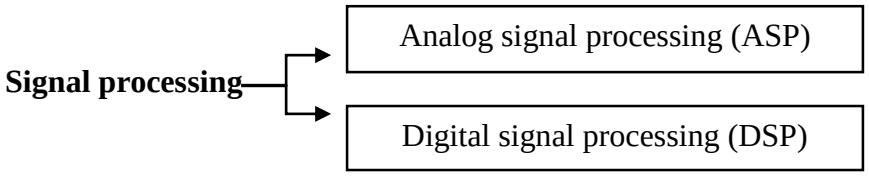
if its value is a function of *M* independent variables. For example, the picture in the following figure is a 2D signal, because the brightness (or Intensity) is a function of two independent variables $I(x, y)$.



In the same concepts, there are **<u>single channel and multi- channel</u>** signals based on the generation source of the signal. Because, signals may be generated by multiple sources or multiple sensors. Such signals are represented in vector form. For $s_k(t)$ is an electrical signal comes from kth sensor as a function of time, where $k = 1,2,3$. Then $p = 3$ signals is defined by a vector $S_3(t) = \begin{bmatrix} s_1(t) \\ s_2(t) \\ s_3(t) \end{bmatrix}$

Note, the color TV picture is a three-channel, three-dimensional signal, while the black-white TV picture can be written as $I\ (x, y, t)$ because the intensity is a function of time, so it is a three dimensional signal.

Processing: the operations applied on the signal to either extraction of useful information to be used or to changing the signals characteristics. In general, **signal processing** can be done in two way to obtain the **processed signal** as shown:



As a conclusion: DSP extracts the desired signal from the undesired signal based on the general three topics:

1- Smoothing
2- Filtering.
3- Predicting.

These topics lead to estimate the wanted signal, which are called the estimation processes. The mathematical representation of the estimation process for the signal $x(t)$ to obtain the estimated signal $\hat{x}(t)$ is:

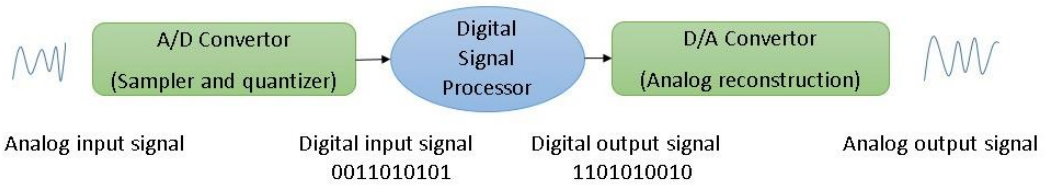
$$x(t) \xrightarrow{estimation} \hat{x}(t)$$

Digital signal processing is implemented in three basic steps:

1. The analog signal is *digitized*, that is, it is *sampled* and each sample *quantized* to a finite number of bits. This process is implemented using an interface between the analog signal and the digital signal processor, which is called Analog- to- digital (A/D) convertor. It needs an analog filter prior ADC to determine the frequency range of the signal before the sampling process.

2. The digitized samples are processed by a digital signal processor.

3. The resulting digital output samples are converted back into analog form using an analog reconstruct, that is the Digital- to- Analog convertor (D/A). An analog filter is also needed after the D/A to remove the sharp transitions from the output of the DAC.



A typical digital signal processing system

Advantages of DSP over ASP

1. A digital programmable system allows flexibility in reconfiguring the digital signal processing operations simply by changing the program.

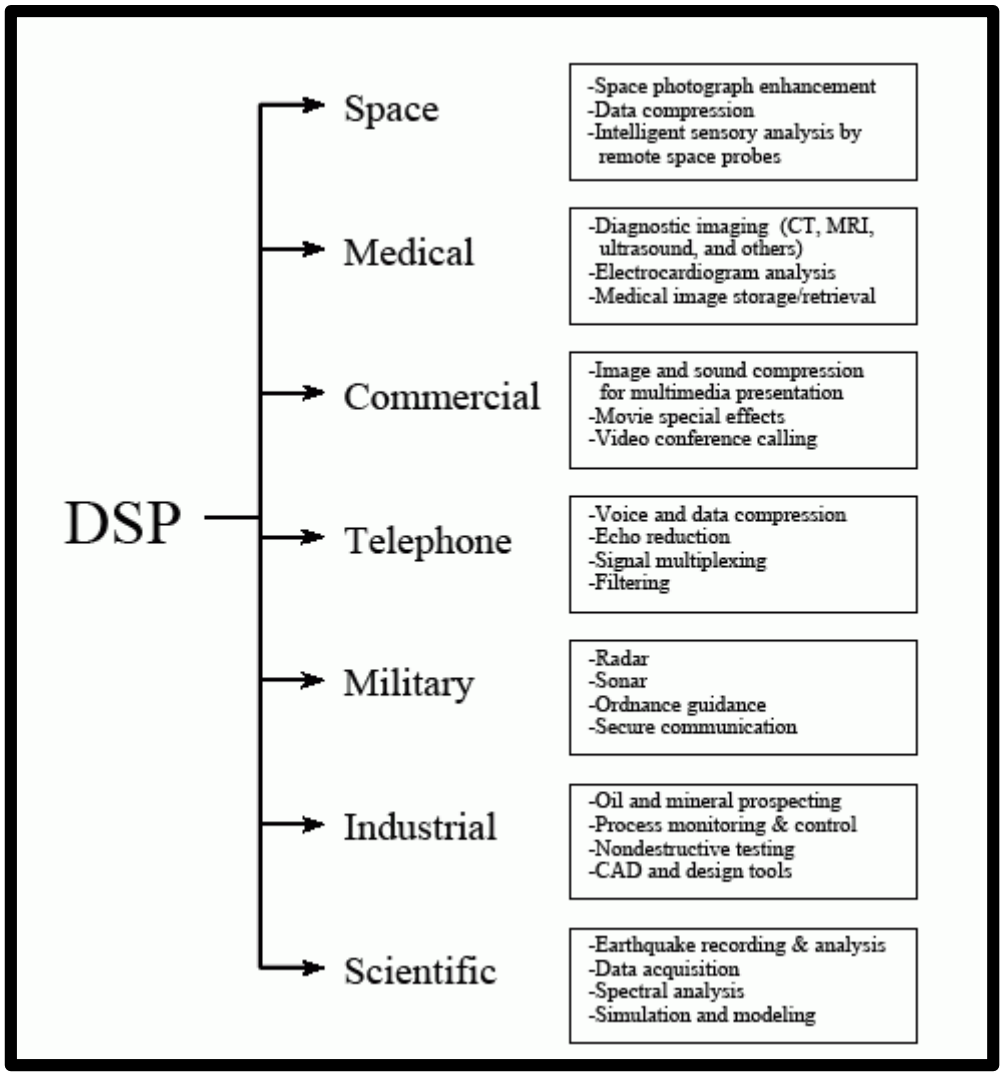
2. Signals and data are increasingly stored in digital computers and magnetic media, and transmitted from one place to another in digital form then processing them digitally. Moreover, the digital signal processor can be programmed to perform a variety of signal processing operations, such as filtering, spectrum estimation, and other DSP algorithms. Beside, depending on the speed and computational requirements of the application, the digital signal processor can be realized more easily.

3. Accuracy considerations also play an important role in determining the form of the signal processor. Tolerances in analog circuit components make it extremely difficult for the system designer to control the accuracy of an analog signal processing system .On the other hand, a digital system provides much better control of accuracy requirements.

However, digital implementation has its limitations, such as the limitation in the speed of operation of A/D converters and digital signal processors. For example, signals having extremely wide bandwidths require fast-sampling-rate A\D conversion and fast digital signal processor.

Some Applications of DSP

Magnetic cards, remote controls, digital entertainment systems, personal computers/networking, copiers/laser printers, new telecommunications systems (e.g., cellular phones, high-speed modems for Internet connection, video teleconferencing systems), health care apparatus, industrial control systems, automotive electronics, computerized billing/banking systems, and voice recognition/ synthesis. All above systems affect the way we live. Each of these applications has developed a deep DSP technology, with its own algorithms, mathematics, and specialized techniques. DSP has revolutionized many areas in science and engineering. In general, the most important applications in science and engineering that based on DSP can be divided as in the following figure:


DSP
Space
-Space photograph enhancement
-Data compression
-Intelligent sensory analysis by remote space probes
Medical
-Diagnostic imaging (CT, MRI, ultrasound, and others)
-Electrocardiogram analysis
-Medical image storage/retrieval
Commercial
-Image and sound compression for multimedia presentation
-Movie special effects
-Video conference calling
Telephone
-Voice and data compression
-Echo reduction
-Signal multiplexing
-Filtering
Military
-Radar
-Sonar
-Ordnance guidance
-Secure communication
Industrial
-Oil and mineral prospecting
-Process monitoring & control
-Nondestructive testing
-CAD and design tools
Scientific
-Earthquake recording & analysis
-Data acquisition
-Spectral analysis
-Simulation and modeling

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