

Digital Signal Processing

The Breadth and Depth of DSP

Moslem Amiri, Václav Přenosil
Masaryk University

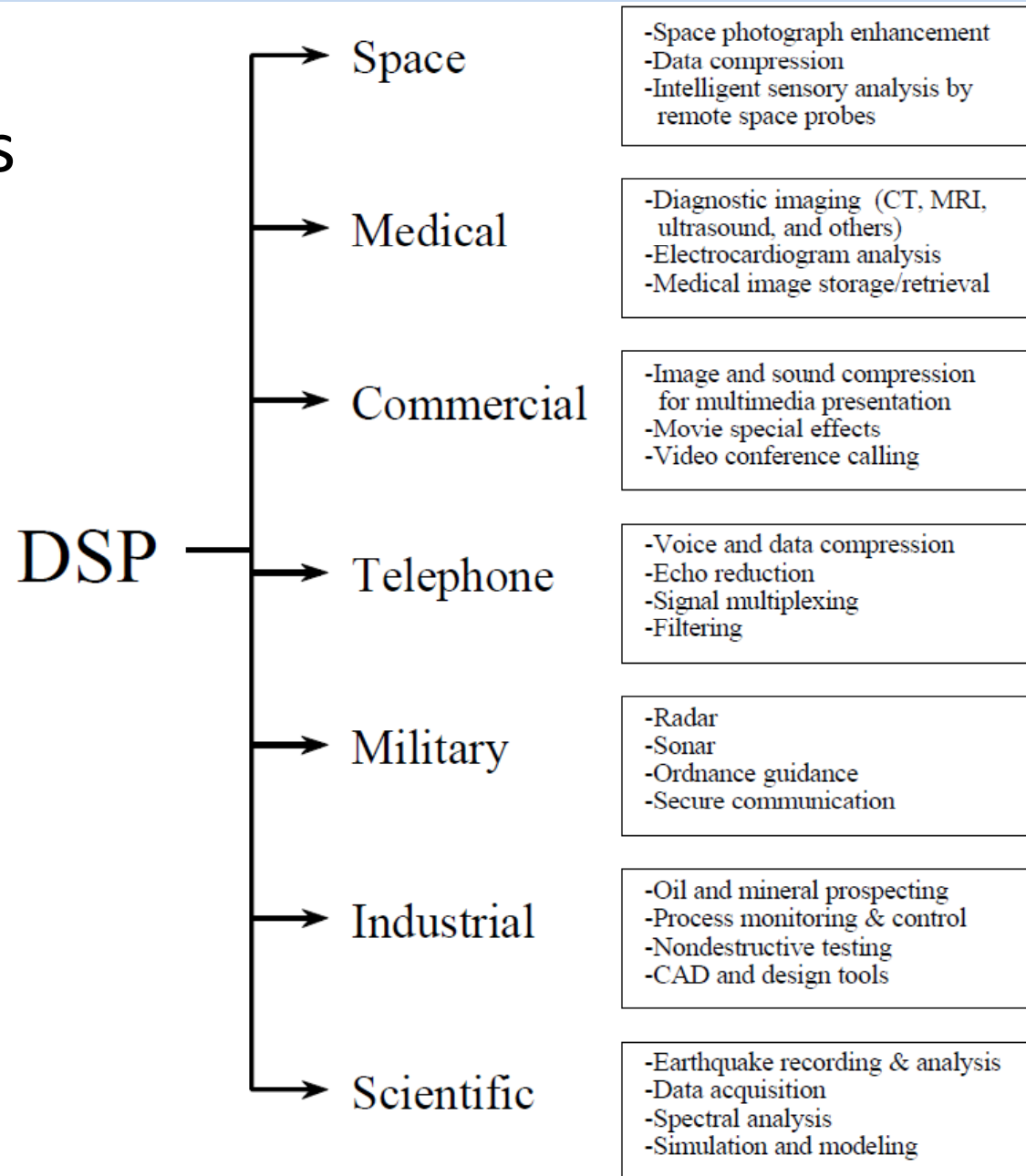
Resource: “The Scientist and Engineer's Guide to Digital Signal Processing”
(www.dspguide.com)
By Steven W. Smith

The Roots of DSP

- DSP
 - Mathematics, algorithms, and techniques used to manipulate digital signals
- Origin of signals
 - Mostly sensory data from real world in analog form
- Roots of DSP
 - 1960s and 1970s
 - DSP was limited to a few critical applications
 - Radar and sonar
 - Oil exploration
 - Space exploration
 - Medical Imaging

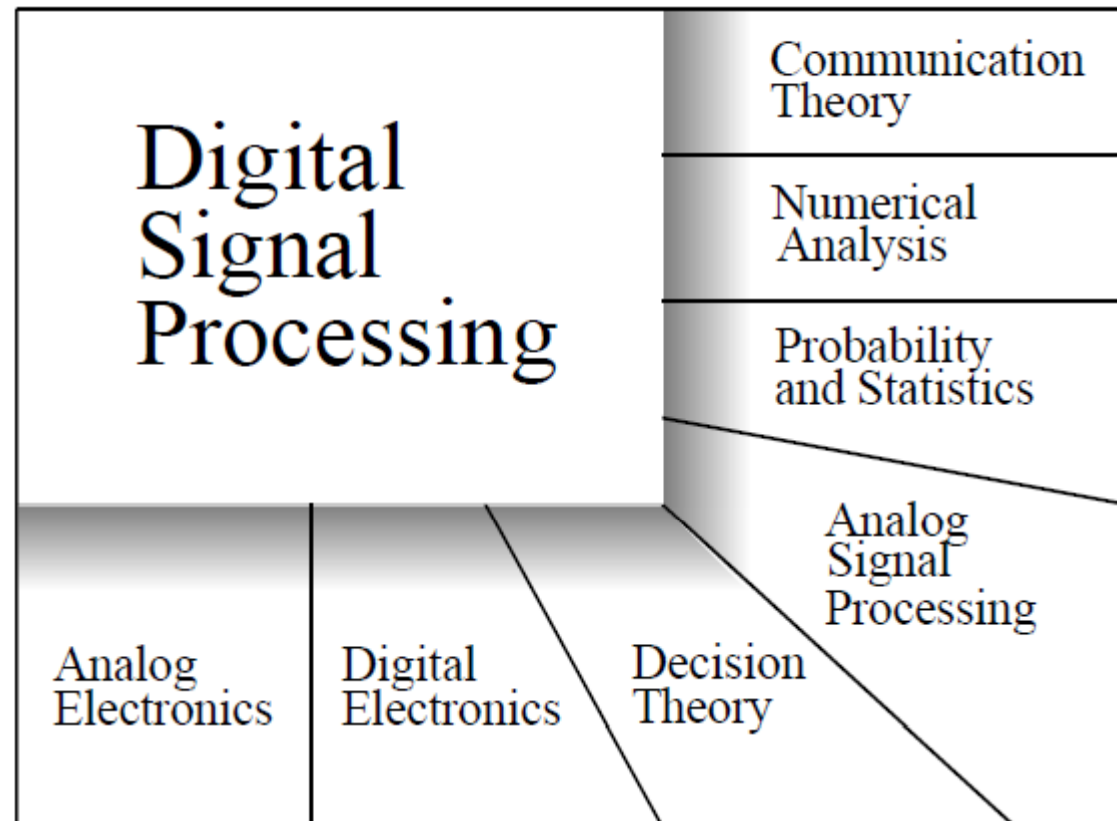
The Roots of DSP

■ New applications of DSP



The Roots of DSP

- Overlapping borders of DSP with many other areas



DSP's Effect on Telecommunications

- Multiplexing
 - Until 1960s, one connection required one pair of wires
 - DSP's function
 - converts audio signals into a stream of serial digital data
 - Bits can be easily intertwined and later separated → many telephone conversations can be transmitted on a single channel

DSP's Effect on Telecommunications

- Compression
 - Information carried by any one sample largely duplicated by neighboring samples → Redundancy
 - DSP's function
 - Data compression algorithms
 - Convert digitized voiced signals into data streams that require fewer bits/sec
 - Vary in amount of compression achieved and resulting sound quality
 - Uncompression algorithms
 - Restore signal to its original form

DSP's Effect on Telecommunications

- Echo control
 - Echoes
 - A serious problem in long distance telephone connections
 - A portion of voice returns as an echo after traveling to connecting receiver
 - DSP's function
 - Measures returned signal – generates an appropriate antesignal to cancel the echo
 - Can also be used to reduce environmental noise by canceling it with digitally generated antinoise

DSP's Effect on Audio Processing

- Music
 - Analog storage and manipulation → degradation
 - Solution → digital data representation
 - Mix down
 - Process of combining individual tracks into a final product
 - DSP's function
 - Filtering, signal addition and subtraction, signal editing, etc.
- Artificial reverberation
 - Simple addition of individual channels → resulting piece sounds frail
 - DSP allows artificial echoes to be added during mix down

DSP's Effect on Audio Processing

- Speech generation
 - Used to communicate between humans and machines
 - 1st approach: digital recording
 - Voice of a human speaker digitized, compressed and stored
 - During playback: uncompressed, converted back into analog
 - 2nd approach: vocal tract simulators
 - Try to mimic physical mechanisms by which humans create speech
 - Operate by generating digital signals that resemble physical mechanisms

DSP's Effect on Audio Processing

- Speech recognition
 - Two steps
 - Feature extraction → each word isolated and then analyzed to identify the type of excitation and resonate frequencies
 - Feature matching → word parameters compared with previous examples of spoken words to identify closest match

DSP's Effect on Echo Location

- Radar (RAdio Detection And Ranging)
 - A radio transmitter produces a pulse of radio frequency energy a few microseconds long
 - This pulse is fed into a highly directional antenna
 - Resulting radio wave propagates away at the speed of light
 - Aircraft in the path of this wave will reflect a small portion of energy back toward a receiving antenna
 - Distance to object calculated from the elapsed time
 - Direction to object is pointing location of directional antenna when echo was received

DSP's Effect on Echo Location

- Radar
 - Two parameters determining operating range
 - How much energy is in initial pulse
 - Noise level of radio receiver
 - Increasing energy in pulse
 - Requires making pulse longer → reduces accuracy and precision of elapsed time measurement → problems with detecting objects at long range and objects' distance
 - DSP's function
 - Can compress pulse providing better distance determination
 - Can filter received signal to decrease noise
 - Enables rapid selection and generation of different pulse shapes and lengths

DSP's Effect on Echo Location

- Sonar (SOund NAvigation and Ranging)
 - Two categories
 - Active → sound pulses transmitted into water – resulting echoes detected and analyzed
 - Passive → listens to underwater sounds
 - DSP's function (same as radar)
 - Pulse generation
 - Pulse compression
 - Filtering of detected signals

DSP's Effect on Echo Location

- Reflection seismology
 - In 1920s, geophysicists discovered structure of earth's crust could be probed with sound
 - A sound pulse sent into ground produces a single echo for each boundary layer
 - Problem
 - Echoes of echoes → echo bouncing between layers
 - DSP's function
 - Isolates primary from secondary echoes

DSP's Effect on Image Processing

- Images
 - Are a measure of a parameter over space
 - Contain a great deal of information
 - Final judge of quality is a subjective human evaluation
- Medical
 - In 1895, Rontgen discovered x-rays could pass through matter → medicine was revolutionized
 - Four problems
 - Overlapping structures in body can hide behind each other
 - Not possible to distinguish between similar tissues
 - X-ray images show anatomy and not physiology
 - X-ray exposure can cause cancer

DSP's Effect on Image Processing

- Medical
 - DSP's function
 - First problem solved by Computed Tomography (CT) scanner: signals digitized and used to calculate slices through body
 - Last three problems solved by using energy other than x-rays
 - Magnetic Resonance Imaging (MRI) uses magnetic fields with radio waves – relies on DSP techniques

DSP's Effect on Image Processing

- Space
 - Low quality of images taken from unmanned satellites and space exploration vehicles
 - DSP's function: improves quality

DSP's Effect on Image Processing

- Commercial imaging products
 - Large information content in images sold in mass quantity
 - DSP's function: image compression