

# SIGNAL PROCESSING AND ITS APPLICATIONS

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# GENERAL OVERVIEW OF SIGNAL PROCESSING

- Digital vs analog vs discrete time.
- Theoretical vs applied.
- Algorithm development vs implementations.
- Applications:
  1. Telecommunications.
  2. Audio
  3. Speech
  4. Analog to digital conversion
  5. Video
  6. Images
  7. Radar
  8. Sonar
  9. Biomedical
  10. Geophysical

# IMAGE PROCESSING

- Image enhancement  $\rightarrow$  dynamic range/histogram modifications.
- Image restoration  $\rightarrow$  deblurring due to motion or being out of focus.
- Image reconstruction from partial information:
  1. Fourier transform phase.
  2. Fourier transform magnitude.
  3. Projection  $\rightarrow$  projection slice theorem.
- Image compression for communications, storage, entertainment, etc. ..

# VIDEO SIGNAL PROCESSING

- Implementation: VLSI architectures need to be resolved for real time operation.
- Algorithmic issues → Compression strategies:
  1. What to quantize:
    - Space domain information: pixels.
    - Frequency domain information: DCT or DFT.
    - Predictive coding: DPCM.
  2. How to quantize:
    - Uniform
    - Max - Loyd.
  3. How to allocate bits:
    - Entropy coding.
    - Arithmetic coding.
    - Hoffman coding.
- Motion Estimation:
  - Reduce redundancy → compression.
  - Frame interpolation → rate conversion.
  - Enhancement.

- Present research topics:
  - HDTV.
  - Video conferencing.
  - Compact disc  $\rightarrow$  1.5 Mb/sec.
  - Video communications over digital networks.

# SPEECH

- Problems in speech:
  1. Analysis and Synthesis.
  2. Voiced/unvoiced discrimination, pitch detection.
  3. Coding → LPC coding, pole zero modeling.
  4. Speech recognition
    - Speaker dependent vs independent.
    - Connected words vs isolated words.
    - Vocabulary size.
    - Extensive training.
    - Error rate
    - Applications of AI for context dependent recognition.

# AUDIO

- Problems in audio:
  1. Generation of signals → music synthesis.
  2. Storage and Transmission of signals → tapes, compact disc players.
  3. Restoration of old signals → Caruso's operas.
  4. Faithful reproduction of signals in the form of acoustic wave → Speaker design.
  5. Adding reverb.
  6. Echo removal.
  7. Adaptive cancellation for room/car acoustics.
  8. Precise analog to digital converter design → Sigma delta converters.

# TELECOMMUNICATION

- Digital versus<sup>S</sup> analog message source.
- Modulation techniques → AM vs FM vs PM.
- Error Correction Codes:
  - Block Codes.
  - Convolutional Codes.
- Compensation for channel nonidealities:
  - Atmospheric Fading.
  - Distortion → Adaptive equalization.
- Viterbi Decoding:
  - ISI.
  - CPM.
  - Convolutional decoding.



## BIOMEDICAL APPLICATION

- Ultra sound.
- Magnetic Resonance Imaging.
- PET.
- X ray Tomography:
  - Projection slice theorem.
  - Application to other tomography problems such as NDE, radar, geophysics.
  - Limited angle tomography.

# RADAR

- Principle of operation:
  - Estimate range by measuring time delay → short pulses.
  - Estimate doppler by measuring frequency of the received signal → Continuous wave such as sinusoid.
  - Tradeoff between range and doppler resolution.
  - Time compression waveforms. → matched filtering.
- High resolution Radar Imaging:
  - SAR → Optical Fourier Transform.
  - ISAR.

## SONAR

- Similar to radar except for operating frequency and passive mode of operation.
- delay and direction of arrival estimation.
- Adaptive beamforming.
- Adaptive nulling to combat unwanted interference.

# GEOPHYSICS

- Applications: Geology, Oil/mineral exploration.
- Signal processing techniques used: DECON-  
VOLUTION: predictive, dynamic homomorphic.

## IMPLEMENTATION ISSUES

- Fixed point versus floating point arithmetic.
- Accumulation of round off errors.
- Filter design and implementation: FIR versus IIR.
- Stability and robustness of algorithms.

## ANALOG VERSUS DIGITAL

- Analog signal processing can handle up to 8 bits of accuracy.
- Advantages of digital:
  - Robustness with respect to aging and temperature.
  - Added flexibility.
- Which one is more appropriate for what?