ELEC 421
Digital Signal and Image Processing

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Course Roadmap for DSP

Lecture	Title
Lecture 0	Introduction to DSP and DIP
Lecture 1	Signals
Lecture 2	Linear Time-Invariant System
Lecture 3	Convolution and its Properties
Lecture 4	The Fourier Series
Lecture 5	The Fourier Transform
Lecture 6	Frequency Response
Lecture 7	Discrete-Time Fourier Transform
Lecture 8	Introduction to the z-Transform
Lecture 9	Inverse z-Transform; Poles and Zeros
Lecture 10	The Discrete Fourier Transform
Lecture 11	Radix-2 Fast Fourier Transforms
Lecture 12	The Cooley-Tukey and Good-Thomas FFTs
Lecture 13	The Sampling Theorem
Lecture 14	Continuous-Time Filtering with Digital Systems; Upsampling and Downsampling
Lecture 15	MATLAB Implementation of Filter Design

Lecture 0:
Introduction to DSP and DIP

Practical Information

- **Lectures and Tutorials (merged):**
  - Tue/Thu: 9:00 am – 11:00 am; MacLeod 3018
- **Instructor:** Siamak Najarian, Ph.D., P.Eng., Professor of Biomedical Engineering (retired)
  - **Email:** siamakn@ece.ubc.ca
  - **Office Hours:** ICICS 371, Tue/Thu: 1:00 pm – 2:30 pm
- **Teaching Assistants:**
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  - Ms. Adriana Cowan (acowan01@student.ubc.ca)

What is DSP and why is it important?

- **Signal processing** is a subfield of electrical/computer/biomedical engineering that focuses on analyzing, modifying, and synthesizing signals such as sound, images, and other forms of data.
  - It involves techniques to optimize transmissions, improve digital storage efficiency, correct distorted signals, enhance subjective video quality, and detect or pinpoint components of interest in a measured signal.
- **The importance of signal processing** lies in its ability to enhance the quality of signals, remove noise, and extract relevant data for further analysis.
  - This field is crucial in various applications across different sectors, including telecommunications, audio and video processing, medical imaging, radar systems, and more.
  - It is the science that enables our digital lives, allowing us to communicate and share information effectively.

What is DSP and why is it important?

- For instance, without signal processing, modern conveniences like digital assistants (Siri, Google Now, Cortana), MP3 and AAC audio compression, and even the ability to share thoughts on social media would not be possible.
- In essence, signal processing is at the heart of our modern world, bridging the gap between technology and our everyday experiences by ensuring that the devices we rely on can interpret and handle data in a meaningful way.

Digital Signal Processing System

- A **DSP System** performs some kind of task on a signal and this depends on the application, e.g.:
  - ***Communications***: modulation/demodulation, multiplexing/de-multiplexing, data compression
  - ***Speech Recognition***: speech to text transformation
  - ***Security***: signal encryption/decryption
  - ***Filtering***: signal denoising/noise reduction
  - ***Enhancement***: audio and image signal processing, equalization
  - ***Data manipulation***: watermarking, reconstruction, feature extraction
  - ***Signal generation***: music synthesis
  - …

Applications of DSP

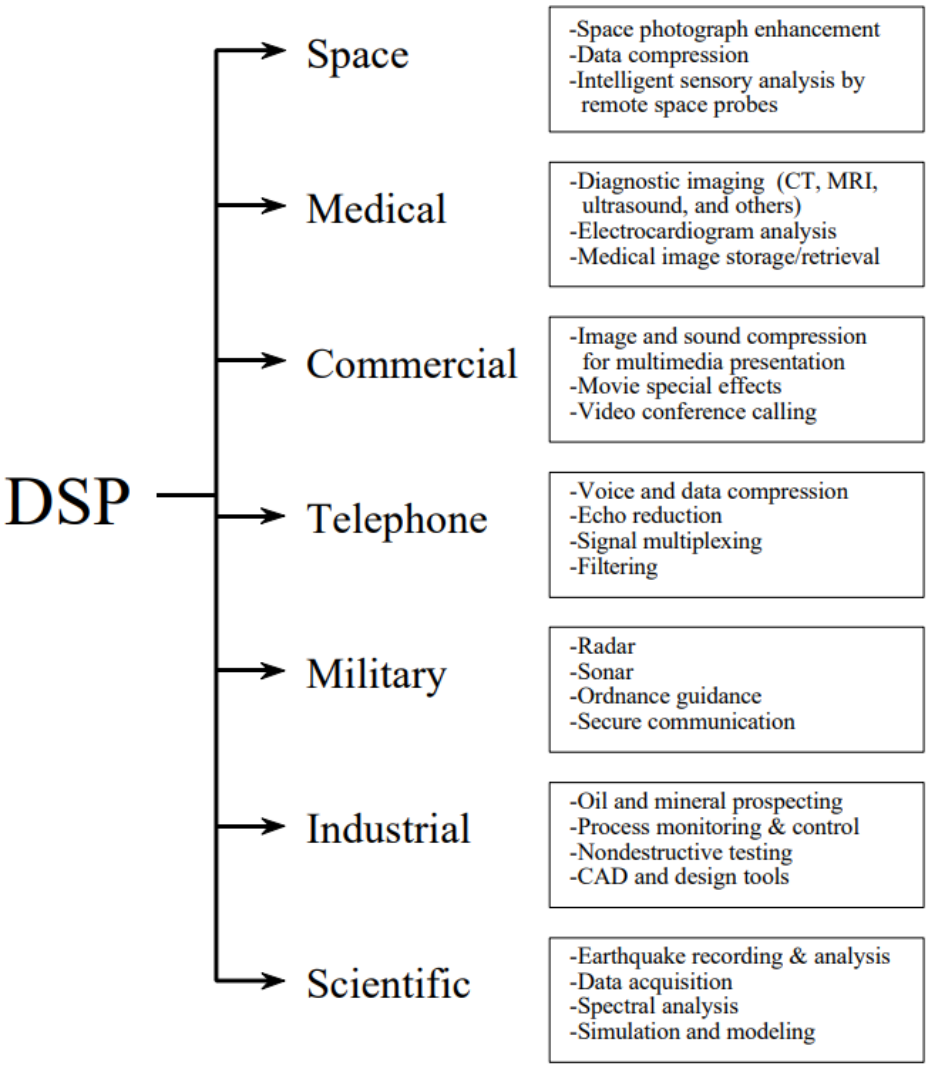


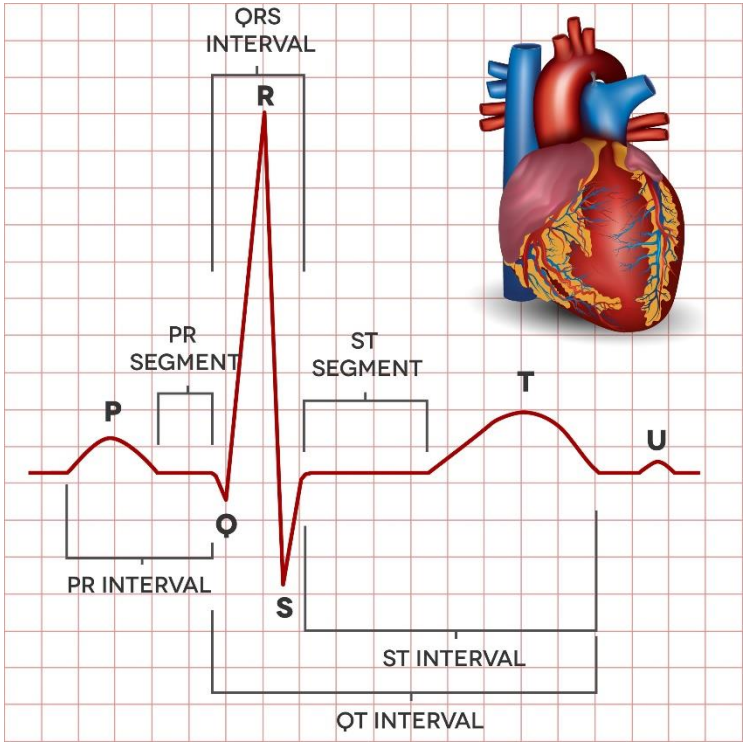
Figure:
DSP has revolutionized many areas in science and engineering. Its application areas are expanding.

Example: Signal Representation

- **What is digital signal?**
  - Speech signal (1D)
  - Image (2D)
  - Video (3D)

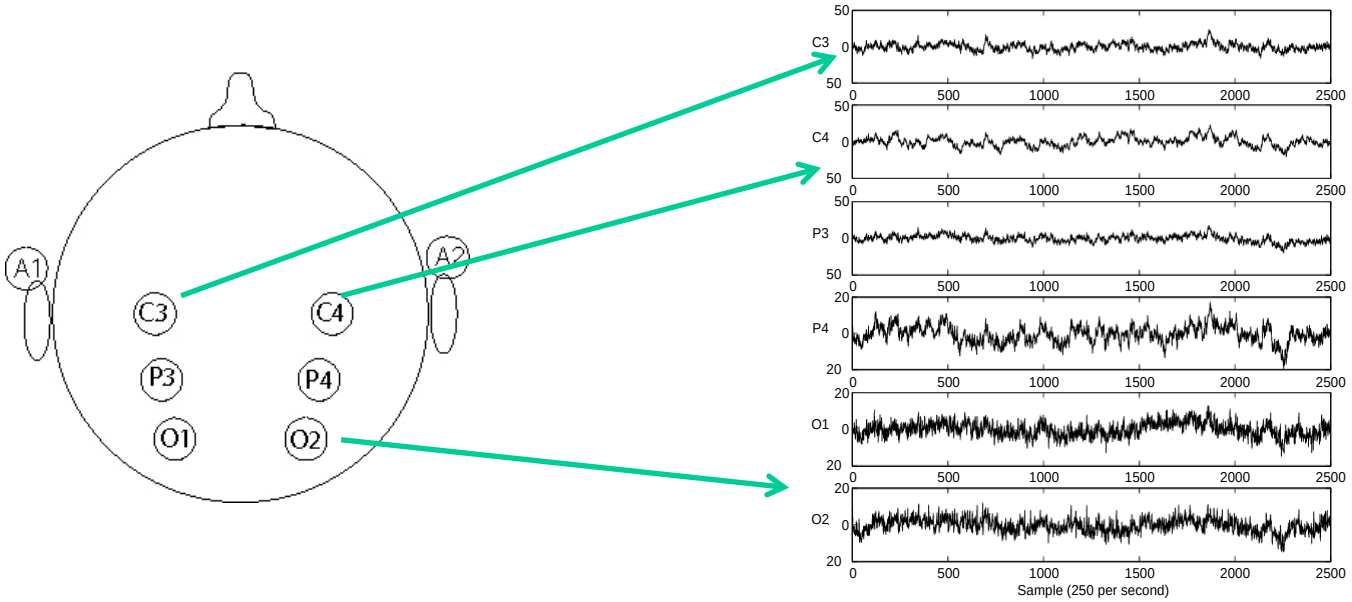
0 0 0 0 2 5 8 10 13 14 14 14 12 11 9 7 5 4 2 1 1 0 0 1 1 1 1 1 2 2 2 3 3
3 3 3 3 3 3 3 3 6 11 20 33 51 72 91 103 105 96 77 53 27 5 -11 -23 -28
-28 -23 -17 -10 -5 -1 0 1 2 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 2 2 3 3 4
4 5 6 7 8 8 9 10 10 11 11 12 12 12 13 14 16 18 20 22 24 27 29 31 34
37 39 42 44 47 49 52 54 55 56 57 57 58 58 57 57 56 56 54 52 50 47
43 40 36 33 29 26 23 20 17 14 12 10 8 7 5 3 2 1 1 0 0 0

- **What is the purpose of DSP?**
  - Speech analysis
  - Transmitting images over Internet
  - Video conference (with live video & audio)
  - Biosignals analysis



Multi-Channel Signals

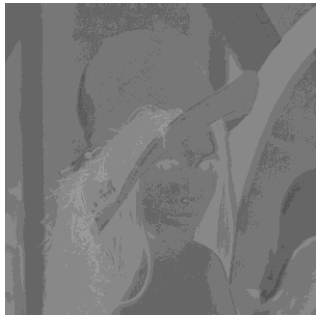
- In some applications, signals are generated by multiple sources or multiple sensors→ represented by a vector
  - Such a vector is called a ***multi-channel*** signal.
- Example: Brain signals



Multi-channel Signal Example: Color Image

RGB

HSV



YCbCr

Deterministic vs. Random Signals

- Signals could be ***deterministic***, with an explicit mathematical description, a table or a well-defined rule.
  - Here, all past, present, and future signal values are precisely known ***without any uncertainty***:

$$S_1(t) = at \qquad \text{or} \qquad S_2(x,y) = ax + bxy + cy^2$$

- In contrast, for ***random*** signals, the functional relationship is unknown.

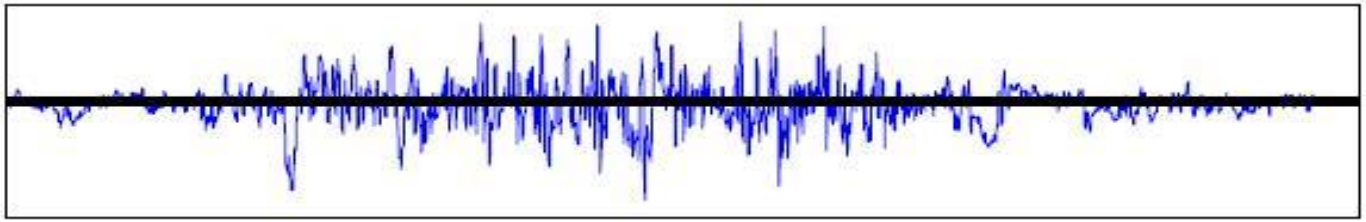
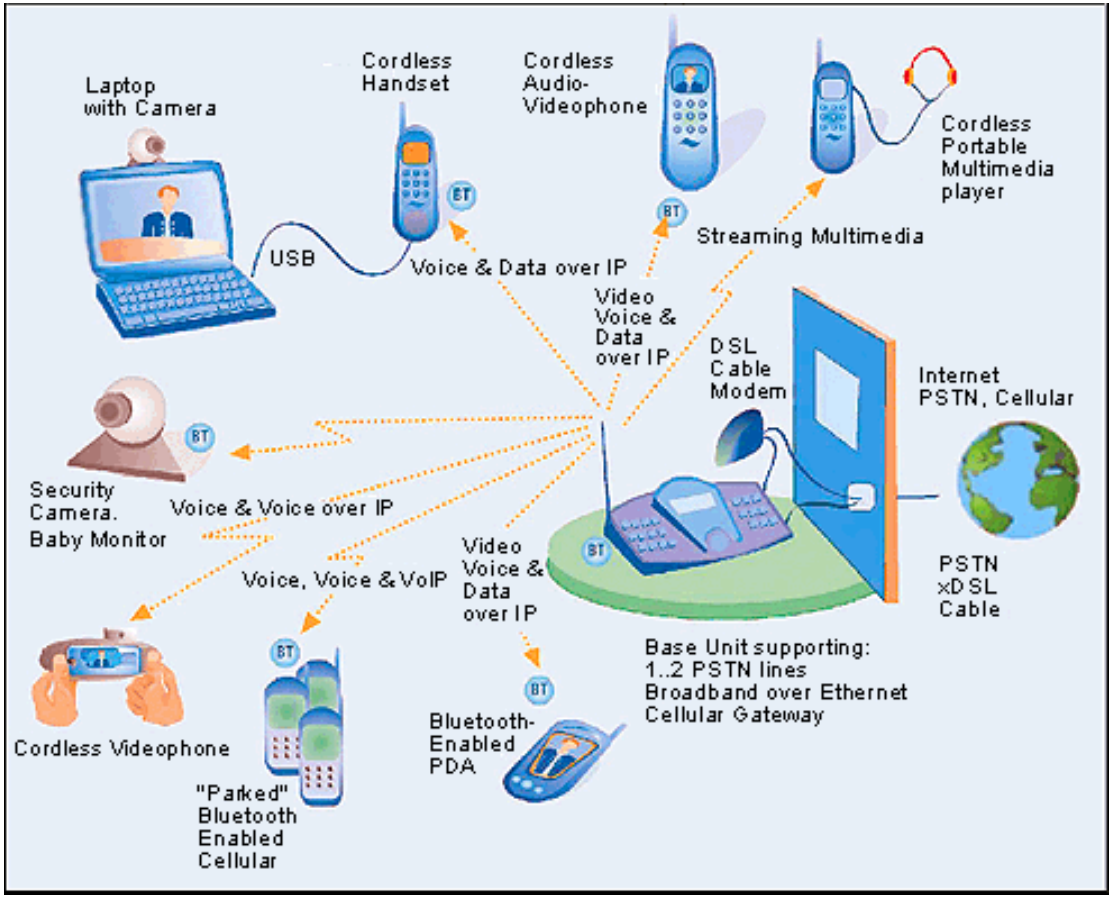


Figure: Example of a speech signal.

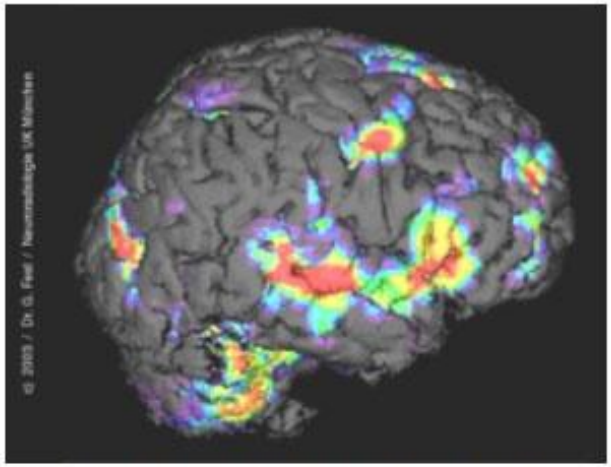
→ *statistical analysis techniques*

Example Application: Wirelessly Connected Home

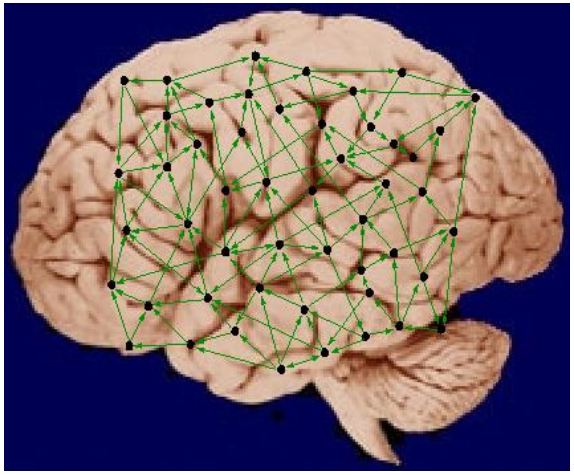
- One application is seamless integration of all types of voice, data, and video communications network capable of providing voice and video intercom, data transfer, internet distribution and remote monitoring and control from anywhere in the world, anytime.



Example Application: Functional Magnetic Resonance Imaging



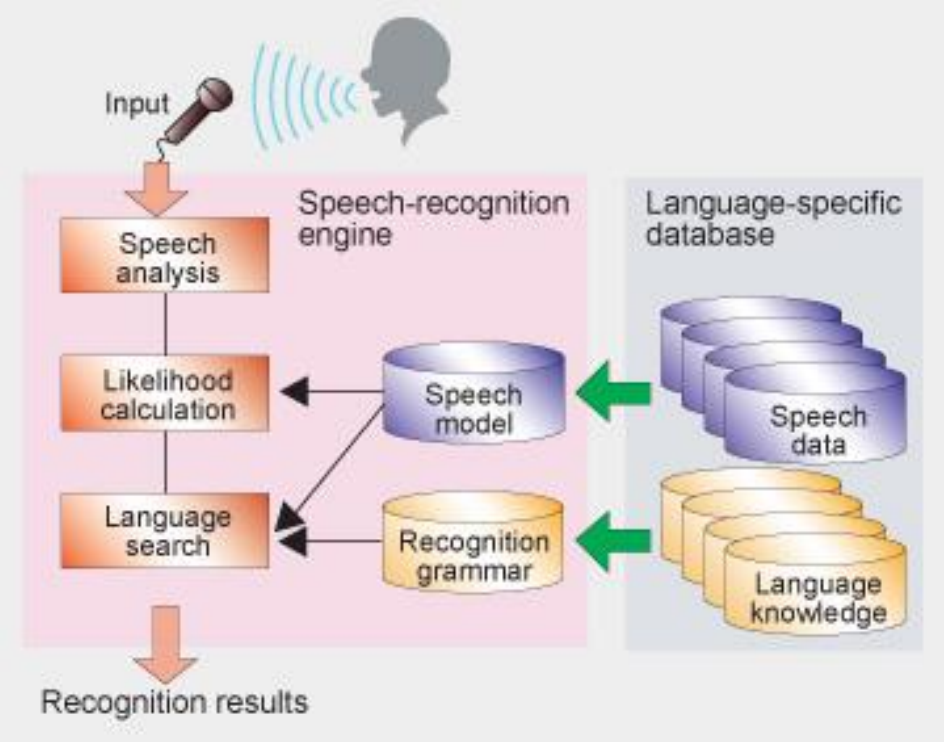
Aktivierung der Hirnoberfläche bei einer Sprachaufgabe



- **Functional Magnetic Resonance Imaging**, or **fMRI**, is a non-invasive imaging technique that measures and maps brain activity.
  - ➢ It does this by detecting changes associated with blood flow.
- This technique relies on the fact that cerebral blood flow and neuronal activation are coupled.
  - ➢ When an area of the brain is in use, blood flow to that region also increases.

Example Application: Audio Processing

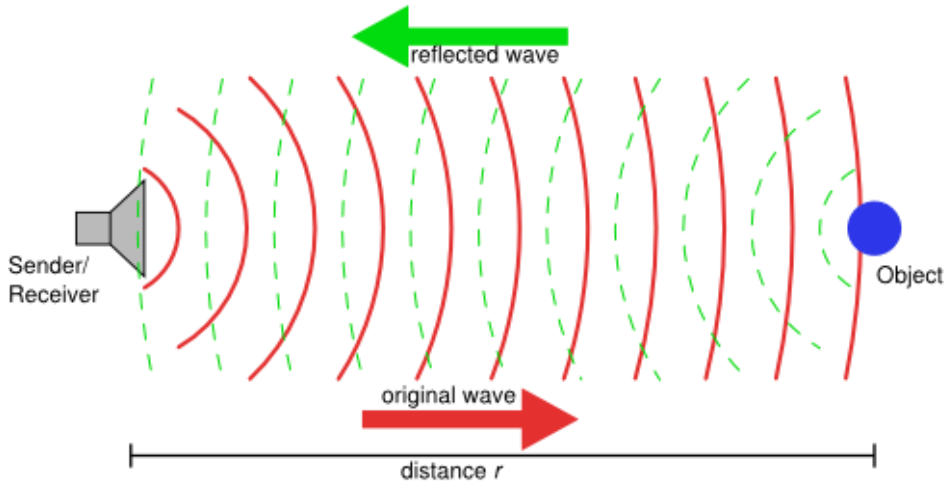
- Applications include speech generation/speech recognition
- ***Speech recognition***: DSP generally approaches the problem of voice recognition in two steps: *feature extraction* followed by *feature matching*.



Source: Canon

Example Application: Echo Location

- A common method of obtaining information about a remote object is to bounce a ***wave*** off of it.
- Applications include radar and sonar.
- DSP can be used for filtering and compressing the data.



Source: CCTT.org

Source: WHIO

Use correlation method

Example Application: Biometrics

- The "Biometrics" field focuses on methods for uniquely identifying humans using one or more of their intrinsic physical or behavioral traits.
- Examples include using face, voice, fingerprints, iris, handwriting or the method of walking, etc.

Source: BBC

Use pattern recognition methods

Example Application: Artificial Intelligence (AI)

AI = Machines learn, sense, think and behave like humans

Data & Data processing

Self-driving car

Alexa

AlphaGo AI

ATLAS Robot

End of Lecture 0