
Digital Signal Processing:

An Introduction and Some Examples of its Everyday Use

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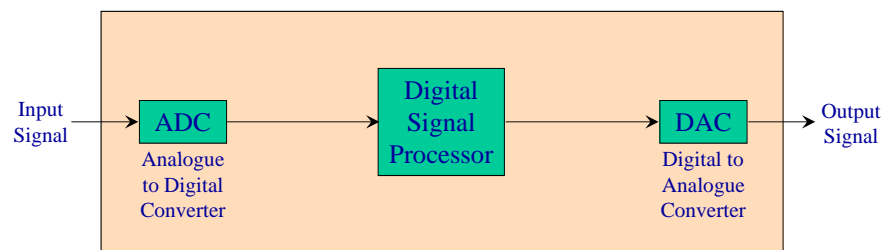
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- What is DSP?
- What is DSP used for?
 - Speech & Audio processing
 - Image & Video processing
 - Adaptive filtering
- DSP Devices and Architectures
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- Summary & Conclusions

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What is DSP?

- **Digital Signal Processing** – the processing or manipulation of signals using digital techniques



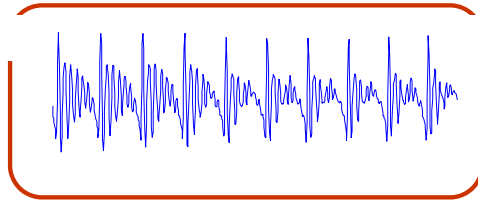
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What is DSP Used For?



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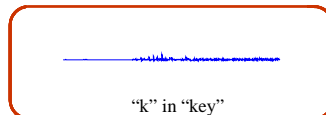
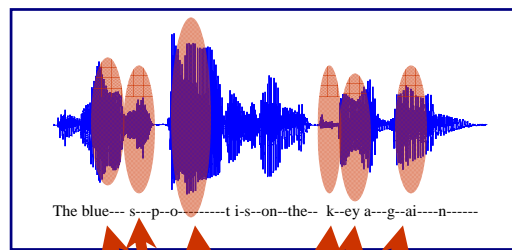
Speech Processing



- Speech coding/compression
- Speech synthesis
- Speech recognition

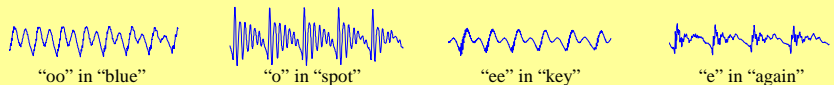
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Some Properties of Speech




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Some Properties of Speech



•Quasi-periodic
•Relatively high signal power

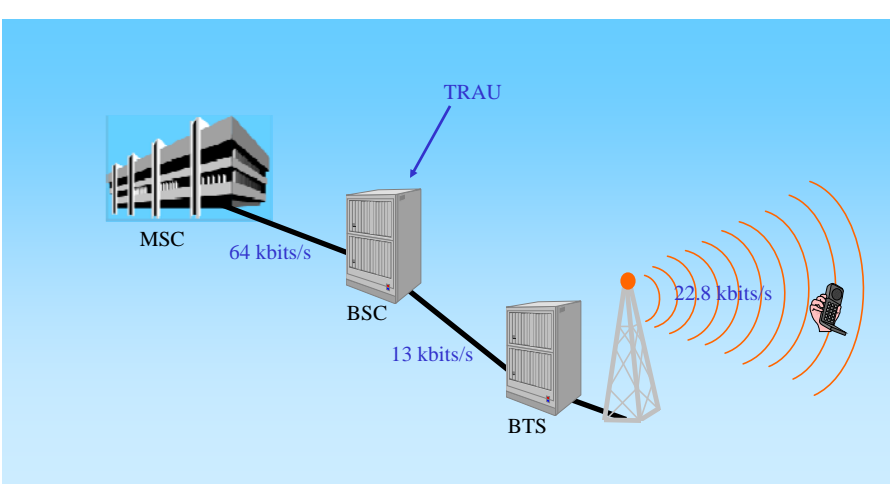
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•Non-periodic (random)
•Relatively low signal power

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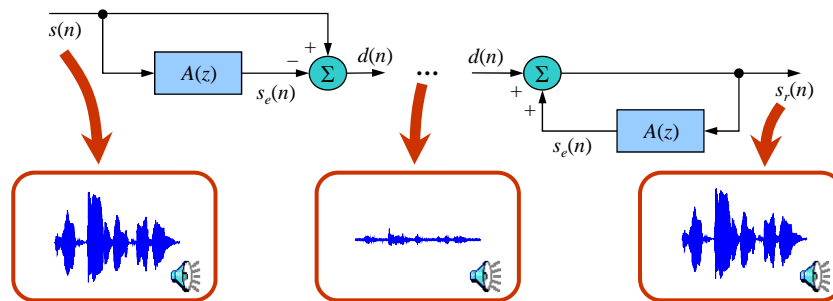
Speech Coding



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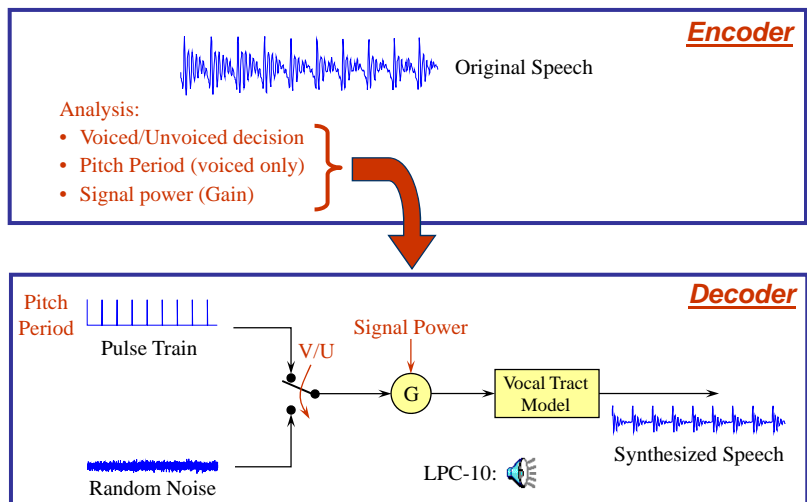
Speech Coding – Linear Prediction

- Try to predict the current sample value;
- Transmit the prediction error.



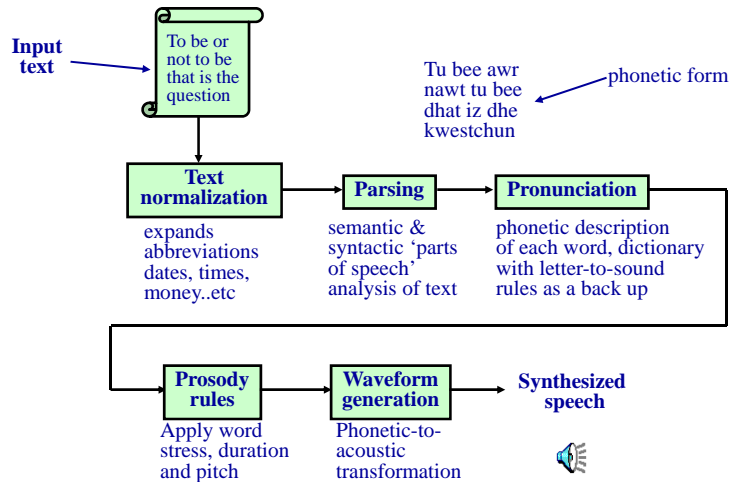
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Speech Coding – Vocoder



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Text-to-Speech Synthesis



Text-to-speech synthesis sounds very natural these days.

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Speech Synthesis Applications

- Speaking clocks
- Spoken (variable) announcements
- Talking emails + talking heads for mobile
- Synthesis of location-based information (e.g. traffic information)
- Interactive systems (e.g. catalogue ordering, Yellow Pages, ...)

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Speech/Speaker Recognition

- **Speech Recognition** – What has been spoken?
 - Speaker dependent – Recognition system trained for a particular person's voice.
 - Speaker independent – Recognition system expected to deal with a wide variety of speakers.
- **Speaker Recognition** – Who has spoken?
- **Not easy...**

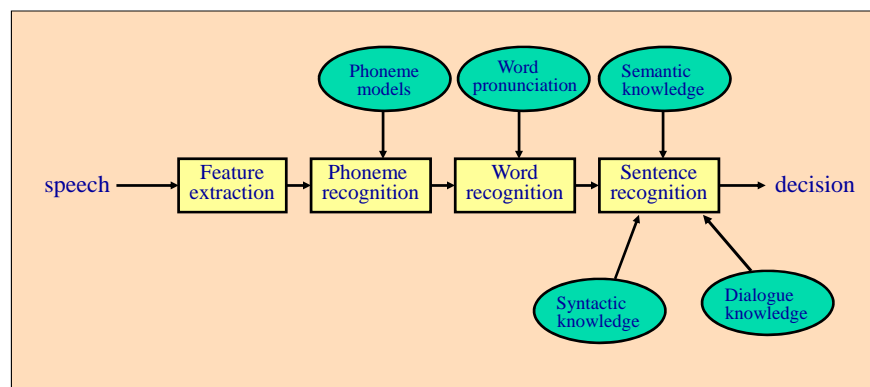
Sometimes there are no gaps between words.

Sometimes there are gaps in the middle of words.

Accents, dialects and Stress exist.

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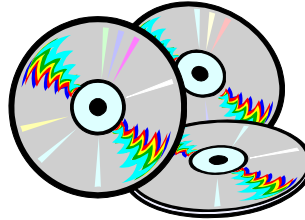
Speech Recognition System



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Digital Audio

- Standard music CD:
 - Sampling Rate: 44.1 kHz
 - 16-bit samples
 - 2-channel stereo
 - Data transfer rate = $2 \times 16 \times 44,100 = 1.4 \text{ Mbits/s}$
 - 1 hour of music = $1.4 \times 3,600 = 635 \text{ MB}$



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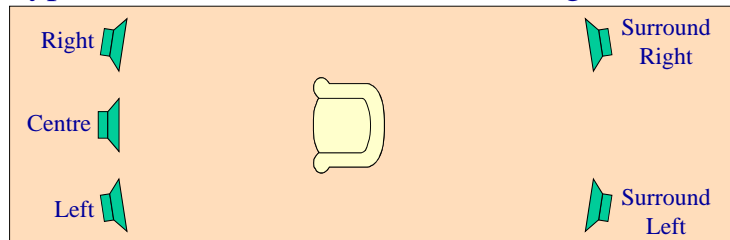
Audio Coding (Cont'd)

- Key standards:
 - MPEG: Layers I, II, and III (MP3); AAC.
 - used in DAB, DVD
 - Dolby AC3, Dolby Digital, Dolby Surround.
- Typical bit rates for 2-channel stereo:
 - 64kbits/s to 384 kbits/s.
- Subband- or transform-based, making use of perceptual masking properties.

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Audio Coding (Cont'd)

- Typical 3/2 multichannel stereo configuration:

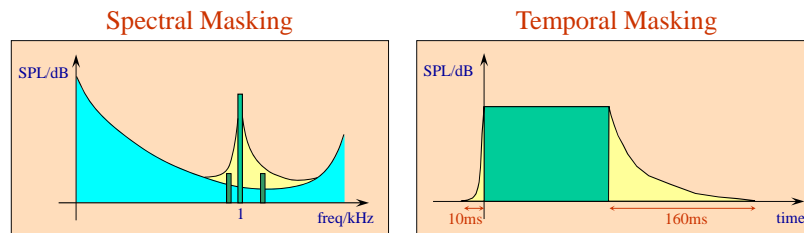


- 5.1 channels (3/2) with LFE channel:
 - Left, Right, Centre,
 - Left Surround, Right Surround,
 - Low Frequency Effects (LFE) (Reduced Bandwidth).
 - LFE loudspeaker can, in general, be placed anywhere in the listening room.

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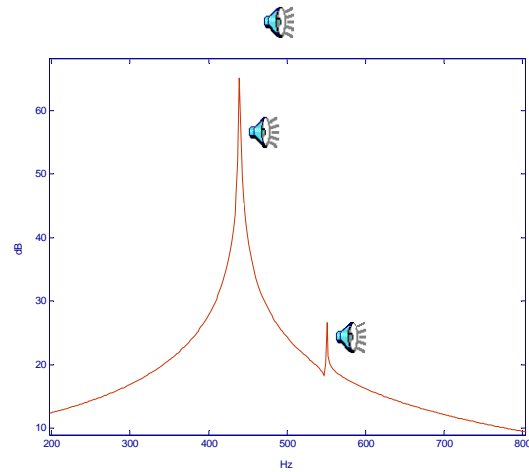
Audio Coding – Masking

- Auditory Masking:
 - Spectral: Strong frequency components mask weaker neighbouring frequency components.
 - Temporal: Strong temporal events mask recent and future events.



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Masking Example



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Image/Video

- Still Image Coding:
 - JPEG (Joint Photographic Experts Group):
 - Discrete Cosine Transform (DCT) based
 - JPEG2000: Wavelet Transform based
- Video Coding:
 - MPEG (Moving Pictures Experts Group):
 - DCT-based,
 - Interframe and intraframe prediction,
 - Motion estimation.
 - Applications: Digital TV, DVD, etc.

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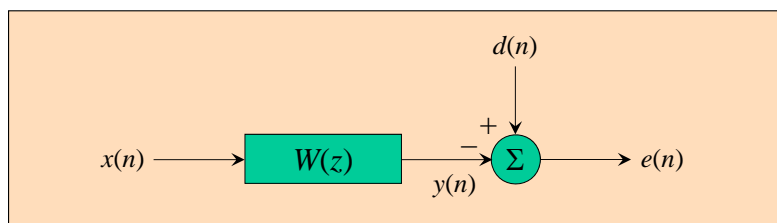
JPEG Example



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Adaptive Filtering

- Self-learning: Filter coefficients adapt in response to training signal.



- Filter update: **Least Mean Squares (LMS)** algorithm

$$\mathbf{w}(n+1) = \mathbf{w}(n) + 2\mu e(n)\mathbf{x}(n)$$

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Adaptive Filtering Applications

- Echo cancellation (telephone lines)
 - Used in modems (making Internet access possible!!)
- Acoustic echo cancellation
 - Hands-free telephony
- Adaptive equalization
- Active noise control
- Medical signal processing
 - e.g. foetal heart beat monitoring

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Some Other Application Areas

- Image analysis, e.g:
 - Face recognition,
 - Optical Character Recognition (OCR);
- Restoration of old image, video, and audio signals;
- Analysis of RADAR data;
- Analysis of SONAR data;
- Data transmission (modems, radio, echo cancellation, channel equalization, etc.);
- Storage and archiving;
- Control of electric motors.

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DSP Devices & Architectures

- Selecting a DSP – several choices:
 - Fixed-point;
 - Floating point;
 - Application-specific devices
(e.g. FFT processors, speech recognizers, etc.).
 - Main DSP Manufacturers:
 - Texas Instruments (<http://www.ti.com>)
 - Motorola (<http://www.motorola.com>)
 - Analog Devices (<http://www.analog.com>)
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Typical DSP Operations

- Filtering
- Energy of Signal
- Frequency transforms

$$y(n) = \sum_{i=0}^{L-1} a_i x(n-i)$$

Pseudo C code

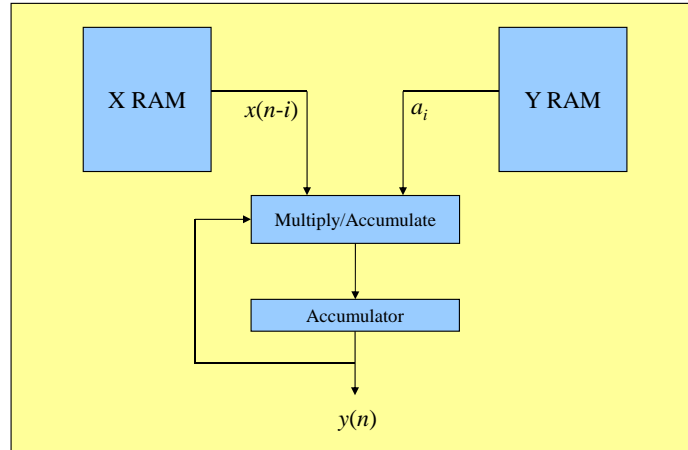
```

for (n=0; n<N; n++)
{
  s=0;
  for (i=0; i<L; i++)
  {
    s += a[i] * x[n-i];
  }
  y[n] = s;
}

```

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Traditional DSP Architecture



N.B. Most modern DSPs have more advanced features.

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DSP at EPSON



**Scotland
Design
Centre**

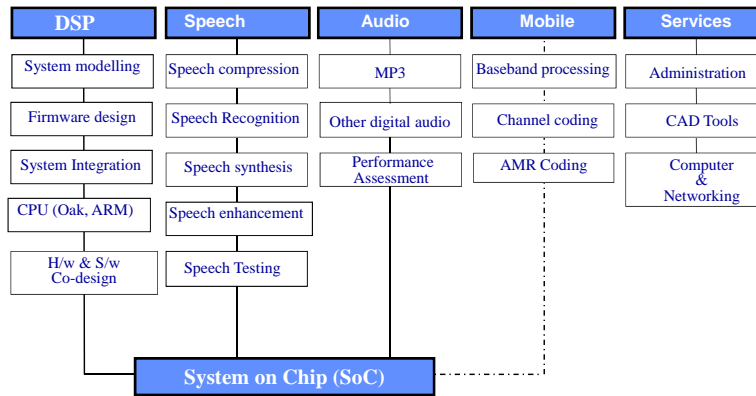


“Energy-saving Firmware”

EPSON Scotland Design Centre develops a broad range of technologies to minimize power consumption and maximize cost effectiveness in mobile DSP applications.

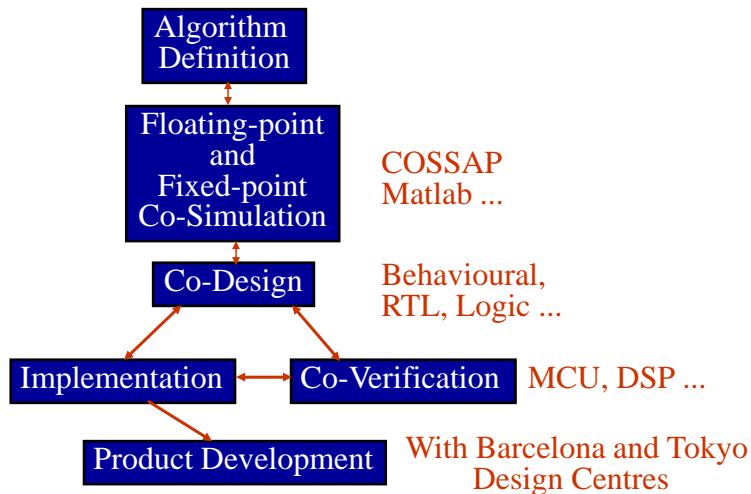
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SDC Core Skills



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SDC Firmware Development



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Summary & Conclusions

- DSP used in a wide range of everyday applications
- Looked at:
 - Speech coding; Speech synthesis & recognition;
 - Image/Video;
 - Adaptive filtering.
- Other areas include:
 - Image analysis (e.g. face recognition, OCR, etc.);
 - RADAR/SONAR;
 - Data transmission and reception;
 - And many more.....!!

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