1.3 Applications

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Applications

- automatic speech recognition
- speaker verification and identification
- monitoring of machines and entire facilities
- character and handwriting recognition
- echo canceling
- radar signal analysis
- automatic analysis of medical data (x-ray, blood count)
- inspection and automatic surveying
- cartography
- quality controlling
- robotic and driverless transportation systems
- traffic monitoring
- autopilots in planes and cars
- natural Human Machine Interaction
- person identification and access control

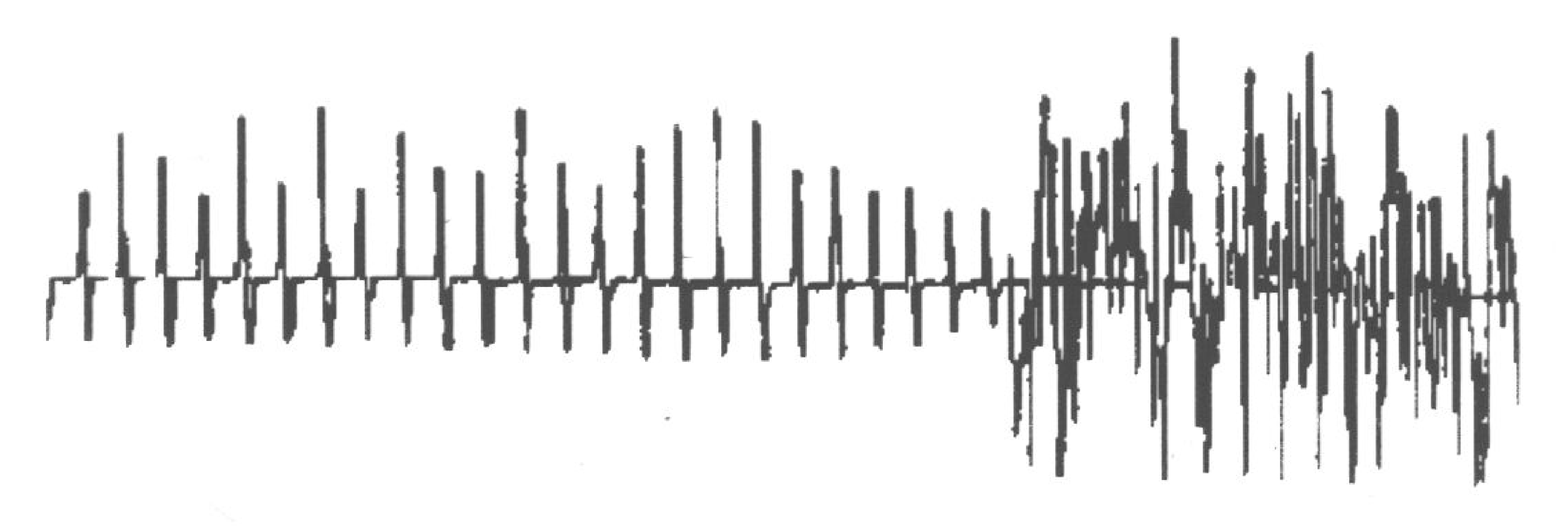
2. Preprocessing and feature extraction

Why feature extraction:

1) transformation to a more suitable parametric representation
2) Data reduction

2.1 Preprocessing in the time domain

2.1.1. Zero-crossings



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2.1.2 Energy

Energy within a certain time window of length K

$$E = \frac{1}{K} \sum_{k=1}^{K} y^2(k)$$

instead

$$E' = 10 \log \left[\frac{1}{K} \sum_{k=1}^{K} y^2(k) \right]$$

2.1.3 Correlation Coefficients

$$r(n) = \sum_{k=1}^{K} y(k) \cdot y(k+n)$$

auto-correlation

also normalized correlation coefficients:

$$r'(n) = \frac{\sum_{k=1}^{K} y(k) \cdot y(k+n)}{\sqrt{\sum_{k=1}^{K} y^2(k) \cdot \sum_{k=1}^{K} y^2(k+n)}}$$

2.1.4 Differentiation

$$\Delta y(k) = y(k) - y(k-1)$$

$$\Delta\Delta y(k) = \Delta y(k) - \Delta y(k-1)$$

$$= y(k) - 2y(k-1) + y(k-2)$$

2.2 Preprocessing in the frequency domain

Time-to-Frequency Transformations:

2.2.1.1 Laplace Transformation

$$y(t) \longrightarrow Y_L(s)$$

time signal — frequency domain

$$Y_L(s) = \int_0^\infty y(t)\, e^{-st}\, dt$$

$$s = \sigma + j\omega$$

Reverse transformation:

$$y(t) = \frac{1}{2\pi j} \int_{\sigma - j\infty}^{\sigma + j\infty} Y_L(s)\, e^{st}\, ds$$

$$= e^{\sigma t} \cdot e^{j\omega t} =$$

$$e^{\sigma t} \cdot \left(\cos\omega t + j\sin\omega t\right)$$

2.2.1.2 Z-Transformation

$\Rightarrow$ discrete Version of $\mathcal{L}$-Transformation

$$y(t) \xrightarrow{t = kT} y(k)$$

Sampling time

continuous signal

time-discrete signal

Rewrite formula for $\mathcal{L}$-Transformation.

$$Y = \sum_{k=0}^{\infty} y(kT)\, e^{-skT}$$

Introduce: $z = e^{sT}$

$$\Rightarrow Y_z(z) = \sum_{k=0}^{\infty} y(k) \cdot z^{-k}$$

$$\mathcal{Z}\{y(k-n)\} = Y(z) \cdot z^{-n}$$

Example: transfer function:

$$H(z) = \frac{1}{1 - az^{-1}}$$

$$\frac{1}{1 - az^{-1}} = \frac{Y(z)}{X(z)} \qquad x \longrightarrow \boxed{h} \longrightarrow y$$

$$Y(z)\left(1 - az^{-1}\right) = X(z)$$

$$Y(z) - a \cdot Y(z) \cdot z^{-1} = X(z) \quad \Big| \; \mathcal{Z}^{-1}$$

$$y(k) - a\,y(k-1) = x(k)$$

$$y(k) = a\,y(k-1) + x(k)$$

Impulse response: $x(0) = 1$

$x(1), x(2) \ldots = 0$

$$y(0) = 0 + 1 = 1$$

$$y(1) = a + 0 = a$$

$$y(2) = a^2 + 0 = a^2$$

$$\Rightarrow y(k) = a^k$$ (impulse response)

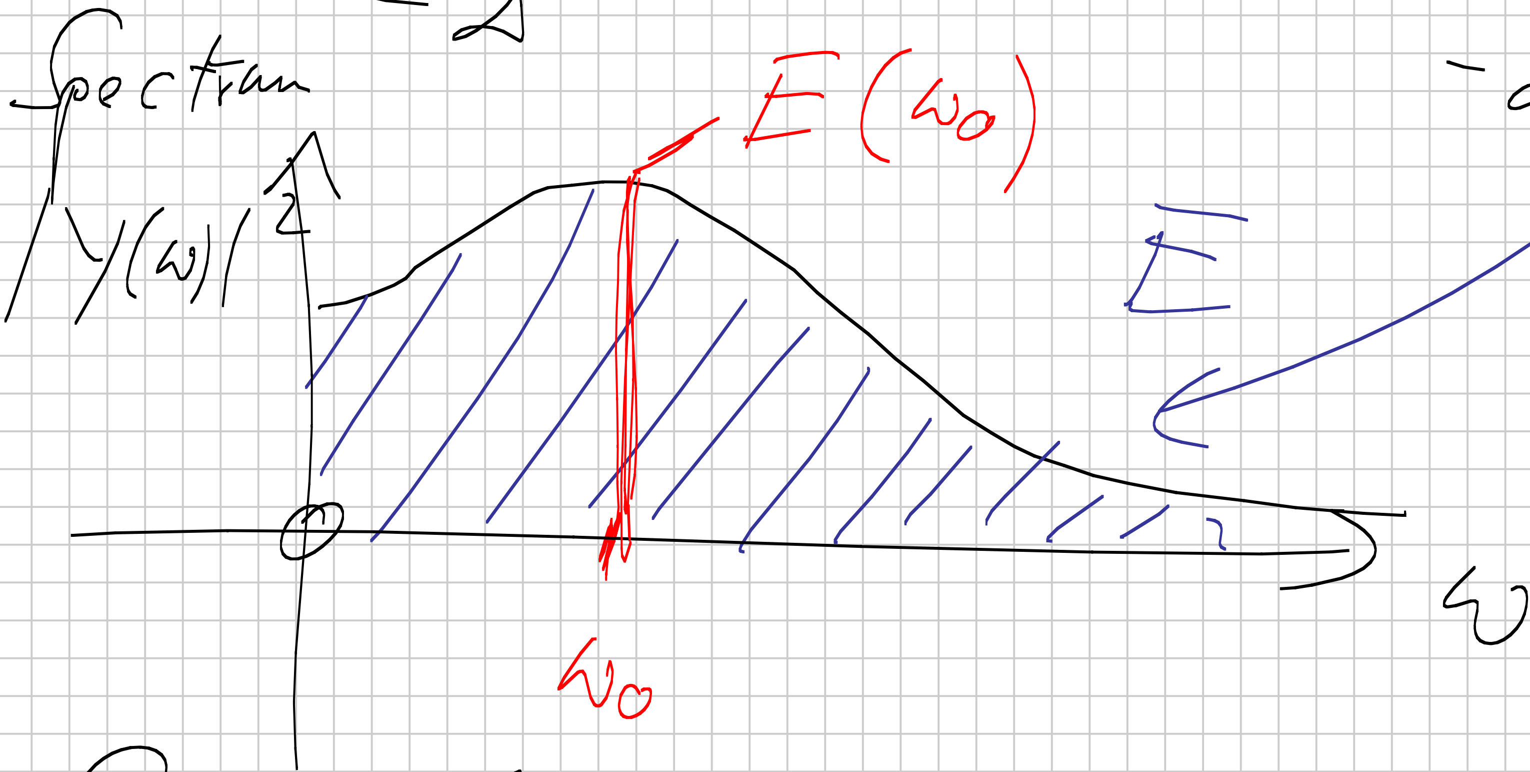
2.2.1.3 Fourier - Transformation

derive from $\mathcal{L}$-transformation by setting $\sigma = 0$, for $s = \sigma + j\omega$

$$Y_F(\omega) = \int_0^\infty y(t)\, e^{-j\omega t}$$

Isometric operator $\Rightarrow$ energy conserving

$$E = \int_{-\infty}^{\infty} |y(t)|^2 \, dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} |Y(\omega)|^2 \, d\omega$$



Reverse transformation:

$$y(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} Y(\omega) \cdot e^{j\omega t} \, d\omega$$

2.2.1.4 Discrete Fourier Transformation (DFT)

time discretization:

$$t = k \cdot T$$

frequency discretization:

$$\omega \rightarrow \omega_n = \frac{2\pi}{T} \cdot \frac{n}{N}$$

$$\Rightarrow Y = \sum_{k=0}^{N-1} y(k)\, e^{-j \frac{2\pi}{\cancel{T}} \cdot \frac{n}{N} k \cancel{T}}$$

$$\Rightarrow Y_{DFT}(n) = \sum_{k=0}^{N-1} y(k) \cdot e^{-j \cdot \frac{2\pi n}{N} \cdot k}$$

discrete frequency

Reverse Transformation

$$y(k) = \frac{1}{N} \sum_{n=0}^{N-1} Y_{DFT}(n) \cdot e^{j \frac{2\pi k}{N} n}$$