Dialogue systems

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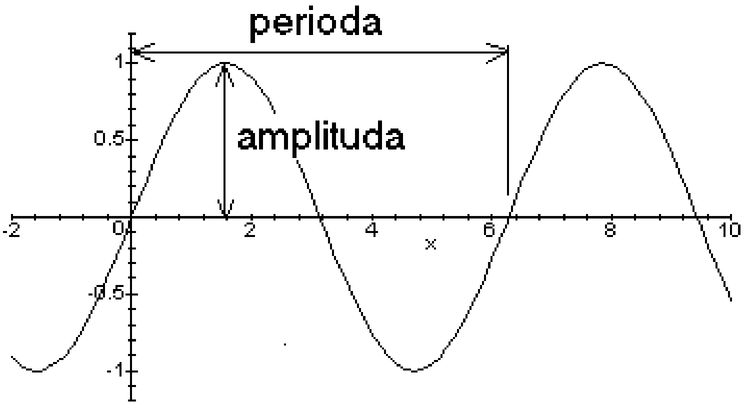
Sound

- Sound
  - oscillation of an environment molecules (air)
  - caused by transmission medium resistance.
- Oscillation of a mass point
  - move of a point from equilibrium position into a place with maximum deflection (an amplitude) and from there to the opposite point with maximum deflection. etc.

Oscillations



- Amplitude – maximum deviation of the osculation.
- Period (T)
  - the time of a repetition of a periodic event.
  - Unit – 1 s (second).
- Frequency (f)
  - the number of periodic event repetition per time unit (usually per second).
  - applies $f = \frac{1}{T}$
  - the unit is 1 Hz (Hertz).

Oscillations

Physical Quantities

- The force acting on the oscillating point:
  - $F = -ks$, k – spring stiffness, s – current spring deflection
  - $F = ma \Rightarrow ma = -ks$, m – body mass, a – acceleration
  - $a + \omega^2 s = 0$ ($\omega^2 = \frac{k}{m}$, ω – angular velocity of oscillatory motion: $\omega = \frac{2\pi}{T}$)
- phase of oscillatory motion: $\psi = \omega t$
- current deflection: $y = y_m sin\omega t = y_m sin\psi$
- current speed: $v = \omega y_m sin\omega t = y_m sin\psi$
- current acceleration: $a = -\omega y_m sin\omega t = y_m sin\psi$

Harmonic vs. Damped vs. Forced Oscillations

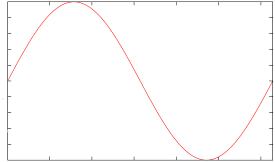
- Harmonic oscillations
  - no external force acts on the body
  - we hardly ever meet him in practice (air resistance, ...).
- Damped oscillation
  - the resistance of the environment acts against the movement
  - the amplitude decreases with time (the distance from the source).
- Forced oscillation, resonance
  - there is an additional periodic force acting on a solid point $G = sin\alpha t$
    - $F = ma = -ky + sin\alpha t \Rightarrow a + \omega^2 y = sin\alpha t$
    - particular solution: $\frac{sin\alpha t}{\omega^2 - \alpha^2}$

Sound

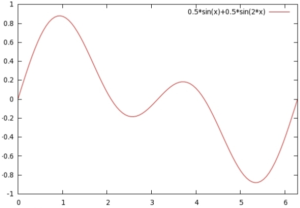
- Sound – mechanic osculation of a flexible environment (air, water, metal, ...)
- Acoustics – a science studding sound (from a Greek akustikos – related to hearing):
  - physical – sound as a physical oscillations
  - physiological acoustics – a creation and a perception of sound by human
  - musical – sound from the musical point of view
  - molecular – relation of acoustic properties and molecular structure.
- Classification of sounds:
  - infra sound – frequency < 16 Hz
  - audible sound – 16 Hz – 16kHz
  - ultrasound – > 16 kHz
  - hyper sound – up to 10^8 Hz – utilized by molecular acoustics for example.

Simple vs. Composed Tone

- Basic (simple) tone – intensity course can be estimated using a simple sinusoidal function.



- Composed tone – linear combination of basic tones.



Acoustic Spectrum of a Sound

- Acoustic spectrum – set of a basic tones forming a particular sound.
- Obtaining spectrum – Fourier transformation:
  - F(x) must fulfil the Dirichlet's conditions
    - a periodic function with period T
    - partially continuous in the given interval (only finite count of a points of discontinuity of a 1st kind)
    - finite count of extremes on the interval
    - defined in endpoints of the interval:

Acoustic Spectrum

Calculation

- Exploits decomposition using the Fourier series:

$$F(x) = \frac{a_0}{2} + \sum_{i=1}^{\infty} a_i cos(i\omega x) + b_i sin(i\omega x)$$

- $\omega = \frac{2\pi}{T}$
- best F(x) approximation using coefficients *a* a *b*:

$$a_k = \frac{2}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} F(x) cos(kx) dx$$

$$b_k = \frac{2}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} F(x) sin(kx) dx$$

- Spectral coefficients values

$$s_k = \sqrt{a_k^2 + b_k^2}$$

Sound Acoustic Spectrum

cont.

- Problem – sound is periodic on a small intervals.
  - analysis on a short interval where is assumed that the sound is periodic.
- Physiological acoustics point of view – spectrum corresponds to resonation of the fibres of the Coorti organ or to the reaction of the corresponding neurons.

Sound Pressure

- Sound pressure
  - Corresponds to the force acting on an area element in the acoustic oscillation environment.
  - For a sine wave:

$$p = p_0 sin(\omega t)$$

    - p_0 – maximum sound pressure during a period
    - ω – angular speed
    - t – time.

Acoustic Intensity and Acoustic Pressure

- Acoustic intensity
  - It expresses the amount of acoustic energy passing through a unit area per unit of a time.
  - Proportional to the square of acoustic pressure.
  - Sound intensity range - from minimal (I_0) to maximum (I_1) acoustic intensity where we can hear a tone with frequency 1 kHz.
  - Sensitivity threshold – $p_0 = 2 \cdot 10^{-2} Nm^{-2}$.
  - Threshold of pain – $p_1 = 10^2 Nm^{-2}$.
  - Range – $2,5 \cdot 10^{13} Nm^{-2}$.

Sound Perception

- Web-Fechner's psychophysical law:
  - The loudness subjectively perceived by a human increases with geometric increase of intensity approximately linearly.
  - We calculate the level of a sound intensity using the formula:

$$L = 10 \cdot log \frac{I}{I_0}$$

  - unit – 1 bel (original bell) [B]
  - The derived unit decibel [dB] is commonly used. ($10^{-1}B$).

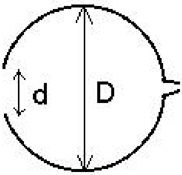
The Acoustic Intensity Approximate Values

- whisper – 10 - 20 dB
- muffled talk – 35 - 45 dB
- symphonic orchestra – 70 - 90 dB
- rock music – 110 - 130 dB.

Fundamentals of a Physiological Acoustics

- Physiological acoustics areas:
  - speech production
  - speech perception.
- Uses Helmholtz's resonance theory.

Helmholtz resonator



- Operation principle:
  - By introducing air into the resonator, overpressure is created in it.
  - It pushes out excess air and creates negative pressure that causes intake of surrounding air.
  - This forms periodic plot:

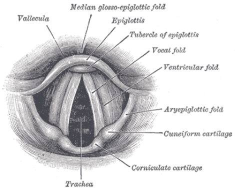
$$f = \frac{75,3}{D}\sqrt{\frac{d}{D}}[Hz]$$

Speech Production Mechanism

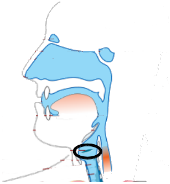
- Speech is created by *vocal system* (placed in *larynx*).
- Vocal cords forms narrow slit and are agitated by passing air.
- Frequency of their vibrations forms the *basic vocal tone* – F_0
- The sound formed in larynx using the vocal cords (vowels, voiced consonants) is modified in *resonance cavities*:
  - laryngeal
  - oral
  - nasopharyngeal.
- The resonance cavities principle is similar to the Helmholtz resonator.

Vocal Cords and the Human Voice Organ Diagram

- Vocal Cords



- Vocal Cords location



Speech Perception Mechanism

- Sound is perceived with the auditory organ.
- Auditory organ:
  - outer ear – captures, concentrates and brings sound waves to the middle ear
  - middle ear
    - transmits the sound energy using a mechanical way between outer and inner ear
    - contains mechanism to making up the difference between outer environment and auditory organ
  - inner ear – converts the sound energy into the excitations that are transmitted into a brain.

Auditory Organ Diagram

Obrázek: Auditory organ diagram

Outer Ear

- Consist of:
  - Auricle – concentrates sound waves into the ear canal.
  - Ear canal – conducts the sound energy (waves) to the tympanic membrane.
  - Tympanic membrane:
    - thin membrane at the end of ear canal – thickness approx 0.1 mm.
    - It amplifies and transfers sound energy to the ossicles of middle ear.

Middle Ear

- Contains:
  - Ossicless of the middle ear:
    - malleus – adjoins the timpanic membrane
    - incus
    - stapes – adjoins the oval window of the inner ear, through which is energy transmitted to the inner ear.
  - Oval window – membrane through which is the movement of middle ear ossicles transferred to the inner ear.
  - Eustachian tube:
    - Tube between middle ear and nasopharynx.
    - Serves to balance the pressure between outer environment and the middle ear, to protect the the auditory organ.

Inner Ear

- Cochlea:
  - Is filled with aqueous solution.
  - An organ in the shape of a snail shell containing Coorti organ.
  - Coorti organ contains approx. 20000 fibres with length between 40 μm – 0,5 mm.
  - Fibres are connected to the nerve endings that conduct impulses to the hearing centre of the brain.
- Balance organ.