Research on (tele)communication tools for people with disabilities - selected topics

Jane 2011, Antoni Grzanka, Poland
General introduction to human voice production: source of energy – air flow
General introduction to human voice production: key elements

- **lungs**
- **vocal cords**
- **vocal tract**
  - **tongue**
  - **jaw**
  - **nasal cavities**
- **lips**
General introduction to human voice production: functions

- information coding
- voiceless part

lips

vibrations, intonation

intensity
Speech: information layers:

- **physical**: acoustic wave
  - intensity
  - time dependant
  - frequency dependant (voice spectrum)
  - space dependant
- **phonetic**
  - phonems ≡ spoken „letters“, spoken “orthography”
- **phonological**
  - spoken „grammar“, semantics, perception
General introduction to human voice production: main dimensions on spectrogram
General introduction to human voice production: formants of phonemes /e/ /y/
Dimensions of voice in human perception: how does the auditory system work?
The examination of hearing by means of a tuning fork Weber Test within the parietal region (A), teeth (B)

Dimensions of voice in human perception: binaural hearing
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>audible frequency range</td>
<td>16-20 000 Hz</td>
</tr>
<tr>
<td>the range of the largest ear sensitivity</td>
<td>1000-3000 Hz</td>
</tr>
<tr>
<td>frequency range of human conversation</td>
<td>200-3000 Hz</td>
</tr>
<tr>
<td>hearing threshold</td>
<td>0 dB HL</td>
</tr>
<tr>
<td>threshold of pain</td>
<td>110-140 dB HL</td>
</tr>
<tr>
<td>hearing damage</td>
<td>150 dB HL</td>
</tr>
<tr>
<td>range of perceived acoustic pressures</td>
<td>0.00002-60 Pa</td>
</tr>
<tr>
<td>number of distinct pure-tones</td>
<td>3000</td>
</tr>
<tr>
<td>frequency resolution</td>
<td>1 Hz at 1000 Hz</td>
</tr>
<tr>
<td>angular resolution</td>
<td>1-4°</td>
</tr>
<tr>
<td>temporal resolution</td>
<td>0.05 sec</td>
</tr>
<tr>
<td>hearing loss vs age (18-50 years)</td>
<td>0.5 dB/year</td>
</tr>
<tr>
<td>hearing loss vs age (over 50 years)</td>
<td>1 dB/year</td>
</tr>
<tr>
<td>average hearing loss at 70 years</td>
<td>37 dB</td>
</tr>
<tr>
<td>Trail eye-to-mouth when reading aloud</td>
<td>0.5-2 sec</td>
</tr>
</tbody>
</table>


Dimensions of voice in human perception: acoustic channel
Dimensions of voice in human perception: speech perception without noise

- 2-syl. (spondee)
- 1-syl.

Intelligibility [%]

SPL [dB]

SDT

SRT

normal hearing

impaired hearing
Speech audiometry with noise

Dimensions of voice in human perception: speech perception with noise
• **Microphone** – acoustic transducer to electric voltage
  • omnidirectional microphones
  • directional microphones
  • arrays of microphones
• Amplifier, mixers, filters – conditioning of the voltage
• **Analog to digital** conversion on a sound card (special integrated circuit)
  • sampling (frequency > 2*highest frequency of the signal)
  • quantization (8 bits, 16 bits, 24 bits, ….)
• Formatting, compression and filing to the sequence of samples

Technologies of speech acquisition by computers: speech production by computers
Source: K. Tokuda, H. Zen, A.W. Black: An HMM-based speech synthesis system applied to English, Proc. 2002 Workshop on Speech Synthesis, Santa Monica USA

Technologies of speech acquisition by computers: speech production by computers
Combination of acoustical and video information in machine speech perception: laryngeoctomees issue
**Sustained vowels recognition rates of acoustic (MFCC) and visual (mouth contour) modalities. Results obtained for all patients, alaryngeal voice (oesophageal and tracheoesophageal) and for pseudo-whisper (PW) group.**

<table>
<thead>
<tr>
<th>input</th>
<th>group</th>
<th>classifier</th>
<th>training</th>
<th>validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFCC</td>
<td>OE,TE,PW</td>
<td>SVM</td>
<td>91%</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N. Bayes</td>
<td>60%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANN</td>
<td>75%</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>OE,TE</td>
<td>SVM</td>
<td>100%</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N. Bayes</td>
<td>92%</td>
<td>91%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANN</td>
<td>90%</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>PW</td>
<td>SVM</td>
<td>85%</td>
<td>70%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N. Bayes</td>
<td>52%</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANN</td>
<td>73%</td>
<td>49%</td>
</tr>
<tr>
<td>Mouth Contour</td>
<td>OE,TE,PW</td>
<td>SVM</td>
<td>81%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N. Bayes</td>
<td>40%</td>
<td>39%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANN</td>
<td>79%</td>
<td>37%</td>
</tr>
</tbody>
</table>


**Combination of acoustical and video information in machine speech perception: labiograms + acoustics**
The application developed as open source (students circle) and promoted by large telecommunication company in Poland

To control the computer without hands – blink browser
Employed persons who, for various reasons, have impaired hearing, and hearing aid often only gives them a chance to continue working.

Older people with physiological hearing loss for whom a hearing aid makes it possible to communicate with the environment.
Modern methods of intervention in hearing problem: hearing implants

1 microphone
2 signal processor
3,4 transmitter, receiver
CL cochlear implant
Co cochlea
AN auditory nerve
ABI auditory brainstem implant
CN cochlear nucleus

Partial deafness treatment - Polish achievement

Gradually increasing clinical material consisting of children with preserved residual hearing have been consistently presented on the international forum by the team of the Institute. Owing to the continuous development of our program of surgical approach to the cochlea through its round window we have been able, as the first team in the world, to single out a completely new group of patients with a hearing impairment, who have extant large population of ganglions in the apex of the cochlea, representing normal tonotopy, thus enabling them to hear low frequency sounds, while being unable to hear high sounds - explains Prof. Skarżyński. Such condition of hearing had been named the partial deafness and it is treated using cochlear implants (Partial Deafness Cochlear Implantation - PDCI). Prof. Skarżyński, as the first surgeon in the world, performed a cochlear implantation in an adult patient with partial deafness in 2002. Fully satisfactory results had been presented in autumn that same year at the Hearing Preservation Workshop in Indianapolis. On following conferences of this series he presented very good results of implantation in further groups of patients. Satisfactory results of hearing preservation in over 93% of adult patients motivated the possibility of applying the same treatment to children. First in Poland and in the world child with a partial deafness had been operated by Prof. Skarzyński in the International Center of Hearing and Speech in Kajetany in 2004. Until present day the homogenous group of patients, children with almost 100% of hearing preservation, is constantly growing. It is the only such group presented in the literature in international congresses. Theoretical rudiments of complementing lost ability of hearing the high frequency sounds with cochlear implants had therefore been confirmed in praxis, proving the possibility of synergy between residual hearing, preserved in different degrees and possibly supplemented by the acoustic stimulation, and electrical hearing.
Brain Computer Interface is an innovative biomedical technology that use brain activity to control computer equipment. Computer can be used to control other devices and systems.

- Can use Invasive and Non-Invasive methods to acquire signals.
- Can use different methods of brain activity measurement (i.e. EEG, (f)MRI, ...).
- No signal input into brain except safe audio-visual feedback stimuli!
- Complex analog measurement systems working with ultra-low-voltage biological signals.
- Advanced digital structure for signal acquisition, processing and decision making.
- External software modules for universal measurement / result visualization.
- Use neuro-feedback mechanisms for closed-loop control.
- Interoperability with existing solutions / open-source software.

- We use self designed EEG equipment and firmware + Open-Source software tools.
- We plan to create inexpensive and affordable BCI/NFB equipment for home users.
Brain computer interface: students' applications.
Brain Computer Interface

Hardware: Self designed and developed from scratch. Existing for comparison.
Brain Computer Interface

Community: Science Festivals, Conferences, Seminars, Picnics, Workshops, ...

Cybernetic Research Student Group, Warsaw University of Technology, http://cyber.ise.pw.edu.pl
"The person who says it cannot be done should not interrupt the person doing it."

I love the Chinese proverb (after Bob Proctor),

Special thanks for help to:
professor Wiesław Konopka (Łódź, Poland)

my students:
  Tomasz Cedro,
  Magdalena Cieślicka