Bionic Ears

Introduction into State-of-the-Art Hearing Aid Technology

Berlin, Dec 28th 2011
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Abstract

In many social situations being hearing impaired is a serious handicap, not only for elderly people. Today's hearing aids are tiny computers that do a decent job in signal processing. During the last years, the progress in this technology was significant, amongst other things by switching from analog to digital devices. Since this field becomes more and more related to computer technology, there is even more improvement to be expected. In particular, it turns into a more and more interesting playground for hackers.

Unfortunately, we are still quite far away from what was promised as the future in that 70es TV series "The Bionic Woman" [1]. Starting with a brief introduction about audiology, I will present current technical solutions (and political non-solutions) for hearing aids. Besides the hearing aids themselves, there exist a couple of interesting peripheral solutions for specific situations such as using the phone, listening to concerts and talks, or just consuming music with an mp3 player. All these not only enhance the user's life, they also open the door for creative hacks. Although the hearing-aid hacking community is still rather small, I will present some current projects and ideas for future ones.

Documentation of this Talk

- slides soon available on http://hackandhear.com
- detailed speaker notes
- recording (hopefully) available
- (maybe) subtitles
Me

- software engineer
- based in Munich
- software geek, not a hardware hacker
- signal processing / datamining background
- medical engineering background
- don't work for hearing aid company
- hearing-impaired for 3.5 years

Disclaimer:
This is a personal pet project.
I am here on my own terms and not on behalf of my employer.
What's this about?

- Audiology
- Getting hearing aids
- Hearing aid models and features
- Peripheral hardware
- Hacking
- Self-tuning
- Conclusions
Audiology
Audiogram

- x-axis: frequency in kHz
- y-axis: volume of signal in db
- healthy person
Audiogram

- green: healthy person
- blue: typical hearing impaired
Audiogram

- green: healthy person
- blue: typical hearing impaired
- red: level of discomfort for hearing impaired
Audiogram

- blue: typical hearing impaired
- yellow: area where speech happens
- hearing aids focus on compensating loss in speech banana

Source: http://en.wikipedia.org/wiki/Speech_banana
How I Hear (Example)

- Song “Sad Robot” by Pornophonique

Source of “Sad Robot”: http://www.pornophonique.de
Source of tinnitus sounds: http://www.ata.org/sounds-of-tinnitus
Getting Hearing Aids
Need Glasses?


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Getting Glasses
Ponies!

Getting Hearing Aids

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Hearing Aid Models and Features
Models of Hearing Aids

In-Ear

Behind-Ear

Cochlear Implant

Source of images:
http://www.flickr.com/photos/Portland_mike/2993507037/
http://www.flickr.com/photos/umhealthsystem/5494712579/sizes/o/in/photostream/
http://www.flickr.com/photos/oaspetele_de_piatra/4581664897/sizes/o/in/photostream/
Visibility of Hearing Aids
Size of Hearing Aids
Hearing Aids
Digital Hearing Aids

- Standard in first world countries
- Make a lot more features possible
- Real time sound processing
  - analyze signal and react to it instantly
Compression

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Frequency Shaping
Compression
Compression

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Frequency Compression

- what if complete loss on one band?
- compress the frequency space
- works only with closed hearing aids
- only one brand (phonak)
Problem: Feedback Loops

- Hearing aid amplifies its own signal
- Whenever something gets close to the hearing aids
- Especially for open hearing aids
“Solution” for Feedback Loops

- Detect “clear” sinus signals
- Send an unhearable flag
- Damp affected frequencies
- Adapt in real time
- Problems:
  - music contains clear sinus signals
  - damped frequencies are needed for speech recognition
- Analog hearing aids did not have a measure against it

Bionic Ears
Cocktail Party Problem
Directional Hearing

- **Human ear:**
  - Use two ears + brain
  - Uses the pinna

- **Hearing aids:**
  - 2 microphones per ear
  - inter-hearing-aid communication
  - situation recognition / different programs
  - automatic focus
  - use the pinna (in-ear hearing aids only)

Directional Hearing
Fore- and Background

- Low frequencies travel further than high ones
- Brain uses this to extract foreground signal and source location
- HAs amplify high frequencies
- HAs filter background signal
Realtime Monitor
Humidity

- Most hearing aids are not waterproof
- No swimming with friends
- No pool parties
- No (social) water sports
- No sweating
- No audiobooks in the bathtub
- No heavy rain
- Drying material necessary

- very recent development: water and dust resistancy
- example: Phonak HAs claim certification of IP67
- no damage due to dust
- 30 min, 1 meter under water: no irreparable damage
Peripheral Hardware
DAI interface

- “direct audio input”
- also called “Euro Adapter”
- cables for all kinds of devices

Pro:
- no interference with wireless devices
- variety of cables available
- used for FM / Bluetooth adapters

Con:
- it's a cable
- too big for really small hearing aids

FM systems

- FM receiver in hearing aids
- FM transmitter connected to source
- Common in the U.S.

- Pro:
  - lots of hardware available
  - different setups
  - (some) standards

- Cons:
  - Interference
  - sound quality
  - incompatibility between systems
Calling on the Phone

- lip reading
- frequency range of phone signal: 300Hz - 3400Hz
- background noise: full range
- signal is altered and unnatural
- missing base
- bad reception
- hearing only in one ear
- feedback loops

Source: http://de.wikipedia.org/wiki/Telefonnetz
Telecoiil and Audio Induction Loop

- telecoil / T-coil in hearing aids
- audio induction loops connected to source
- phone, room installation, cars, adapters
- technology rather old
- widely used in Europe
- cons: interference, sound level differences when moving head, high initial costs
- pros: microphones are automatically switched off, standard in even for new phones, some hearing aids use both ears, DYI kits available

Source: http://en.wikipedia.org/wiki/Audio_induction_loop
Bluetooth

- no hearing aids available with Bluetooth (yet)
- too much battery consumption
- adapters via telecoil, DAI, proprietary protocols
Phonak ICOM

- example of a wireless adapter
- uses telecoil to talk to hearing aids
- interfaces: DAI, aux-in and bluetooth
- FM systems via DAI
- warning regarding pace makers

Source: http://www.remorina.com/clients/eBay/images/icom/iCom_02.jpg
Siemens Tek

- adapter + remote control
- proprietary NFC protocol between adapter and hearing aids
- signal around 3.3Mhz
- compatible with any bluetooth speaking source (in theory)
- mobile phones, land line phones, computers
- comes with an additional transmitter for TV
- costs: 400 EUR (no insurance coverage)
- new version “mini tek”

Siemens Tek w Transmitter
Siemens Tek Inside

- coupled with hearing aids using hearing aid tuning software
- identifies with 7-character serial number
- latency is crucial (encryption?)
- bluetooth pin “0000”
- ear-2-ear communication unauthenticated
Hacking “Scene”

- barely existing
- devices too expensive
- mostly: compatibility issues, asking for technical advice
- a little hacking on peripheral hardware

http://hearingaidhacks.livejournal.com/
DYI Bluetooth Adapter
by Gertlex

In this album... you see my dissection of various electronics, followed by a not quite complete glimpse of the steps I took in modifying these headphones to have two audio jacks. These audio jacks are used for DAI cables that plug into my hearing aids.

Source: http://www.flickr.com/photos/gertlex/sets/72157603510310486/
DYI Bluetooth Adapter
by Gertlex
DYI Bluetooth Adapter
by Neil Ferguson

Source: http://gfern.com/btha/btha.html
Self-Tuning
Tuning

- special hardware: hipro (serial/usb/bluetooth)
- software: noah + modules for each brand
- sold only to doctors and audiologists
- medical equipment (no ebay etc.)
- there is a self-tuner “scene”
- no customer support, no warranty
- exception: americahears.com
Hipro (Serial Version)
Hipro-HA interface
Hipro (Bluetooth Version)
Tuning Software

Frequency Shaping

Maximum Power Output

Compression

Sound Management

Microphone / Bluetooth

Instrument Settings

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Big Brother
Cochlear Implants
Cochlear Implants

Source of images:
http://www.flickr.com/photos/yaccesslab/5431069155/
http://www.flickr.com/photos/oaspetele_de_piatra/4581664897/sizes/o/in/photostream/
Cochlear Implants

- makes deaf people hear
- surgical insertion of device
- destroys any remaining hearing
- surgery might affect other nerves
- signal is different: brain has to adjust
- technology usually 5 years behind
- no standards, no interoperability between brands
Conclusions
Want!

- better service
- consideration of young people's needs
- better signal processing
- (open) standards
Ideas

So einfach – Apps für alle Anforderungen

Wir haben die Audéo S Apps in vier Hauptbereiche zusammengefasst.

- “hearing aid app market”
- crowdsourcing
- language / speaker / location specific programs
- use info from smartphone
- write your own filters?
Thanks!

- Questions?
- Slides and speaker notes on hackandhear.com
- Give Feedback, please!

Credits:

- Heike Pott
  heike-pott.de
- LupusE, Nicolas
- Habo, Jump
- Kevin, the Chaoswelle guys
- ThinkPad, Heiko
- and all I forgot to mention ...