CIRMMT Centre for Interdisciplinary Research in Music Media and Technology

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Headphones: technologies, devices, and applications

Workshop presented by CIRMMT RA-1: Instruments, devices, and systems
April 19, 2017
13h30-16h30

13h30-14h00: D. Quiroz
Smyth realiser: virtual surround technology

14h00-14h20: R. Bouserhal, T. Falk, J. Voix
Speech quality enhancement of in-ear microphone speech for advanced hearables

14h20-14h40: O. Valentin, G. Cretot-Richert, M. De Vos, M.Bleichner, J. Voix
EARtrode, an in-ear custom-fitted EEG-based BCI earphones

14h40-15h00: R.-E. Gaskell
Graphene membranes for high fidelity headphone drivers

15h00-15h20: W. Woszczyk
Multi-driver headphones

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A measurement-based approach in determining the sound quality of headphones

15h40-16h00: M. Landry, N. Laperle
EERS™: A device for the connected protected IOT worker

Smyth realiser: virtual surround technology
Diego Quiroz
13h40-14h00

Smyth Virtual Surround (SVS) is a revolutionary audio process that emulates, in headphones, the complete experience of listening to actual loudspeakers in an actual room, in up to eight-channel surround sound. The emulation includes the precise localisation of all the speakers in the room, the room acoustics, and the response of the speakers and all electronics in the emulated system. The emulation is essentially perfect, meaning that in immediate A/B comparison between the actual speakers and the headphones, listeners say the two are indistinguishable.

The weakness of headphones has been their inability to create a spacious and completely accurate sonic image in three dimensions. Some "virtual surround" processors have made incremental progress in this regard. Sounds coming from various directions are altered as they encounter the shape and dimensions of the head and upper torso, and the shape of the outer ear (pinna). Our brains are highly sensitive to these modifications but we do not hear them as tonal alterations; rather we experience them, quite accurately, as localisation up, down, front, back, or in between. This acoustic alteration is called the Head Related Transfer Function or HRTF. The Realiser employs three critical components not seen in the other products: personalisation, head tracking, and the capture of the properties of any real listening space and sound system.

This breakthrough has far-reaching benefits which audio professionals, home listeners, and game players are only beginning to assess. The relationship between the listener, the listening room, and the sound system is changed completely.

Speech quality enhancement of in-ear microphone speech for advanced hearables
Rachel Bouserhal, Tiago Falk, Jérémie Voix
14h00-14h20

Communicating in noise is a difficult task for people wearing Hearing Protection Devices (HPD) in noisy industrial environments. In fact, the number one reason why workers chose not to wear HPDs in the workplace is that HDPs are a barrier to communication. This work provides a simple yet effective technique to provide workers with enhanced quality communication while maintaining appropriate hearing protection. An intra-aural hearable containing an in-ear microphone, a miniature loudspeaker, and an outer-ear microphone, with wire wireless radio capabilities and a link to a digital signal processor is used to achieve this task. First, using the in-ear microphone and the passive attenuation of the hearable, a speech signal is captured with a relatively good SNR, even in extremely noisy situations. The noise is further reduced using a normalized least-mean squared error adaptive filtering technique. The in-ear microphone speech quality is enhanced by extending its bandwidth through exploitation of nonlinear operators applied to the excitation signal. The technique is validated through subjective and objective measures, both showing statistically significant improvements in speech quality.

EARtrode, an in-ear custom-fitted EEG-based BCI earphones
O. Valentin, G. Cretot-Richert, M. De Vos, M.Bleichner, and J. Voix
14h20-14h40

Brain-computer interfaces (BCI) can directly translate human intentions into discrete commands, bypassing the motor system. Most non-invasive BCI systems currently in use are based on electroencephalography (EEG) recording technology. While traditional EEG-based BCIs achieve high information transfer rates, these systems are facing important limitations. First, they cannot be used in daily life as they are bulky and sensitive to movement. Second, the scalp caps used to position electrodes are inadequate for social settings. To overcome these limitations a portable and unobtrusive ear-EEG recording system was developed and tested against laboratory-conscribed scalp-EEG. The ear-EEG system senses brain-electrical signals from in and around-the-ear, using custom-fitted earpieces. The current study objective was to assess if ear-EEG could produce similar results to conventional EEG apparatus. Miniaturized wet Ag/AgCl electrodes were installed in a custom-fitted EERS/SonoFit™ in-ear audio platform. This in-ear audio platform was coupled with a behind-the-ear piece forming a 5 mini-electrodes interface. Event-related potentials obtained from an auditory oddball and a mismatch negativity paradigm were collected while recording brain activity simultaneously with this setup, dubbed "EARtrode", and scalp-EEG technology. Although EARtrode's signals had lower amplitudes, resulting signal-to-noise ratio and condition effect size were similar for both methods. As a consequence, EARtrode is a promising candidate for future small, mobile, and unobtrusive BCI platforms. In the long term ear-EEG systems could be merged with other audio devices, such as hearing aids and headphones, to build next-generation devices that dynamically adapt to the listener's intentions and state changes.

Graphene membranes for high fidelity headphone drivers
Robert-Eric Gaskell
14h40-15h00

Graphene is a single layer hexagonal crystal lattice of carbon atoms with exceptional mechanical and electrical characteristics. The mechanical advantages of Graphene stem from its low mass and high stiffness, which are superior to any other known material. Researchers at McGill University have developed a way to deposit Graphene that has been functionalized with Oxygen groups into formed membranes for use in loudspeakers. The high stiffness of the material reduces speaker "break-up", improving sound quality. Its low mass allows for more energy efficient loudspeakers, a big advantage for wireless audio devices such as Bluetooth headphones. This McGill-based technology is being commercialized by the start-up company ORA who has made prototype headphones to show off the performance advantages of this Graphene loudspeaker technology. Using Graphene drastically improves the high-frequency characteristics of headphone drivers reducing the perception of "harshness" and improving localization cues. This talk will explain this exciting new loudspeaker technology and show measurements of improvements in headphone performance.

http://montrealgazette.com/news/local-news/mcgill-born-technology-aims-to-revolutionize-headphones-speakers
https://www.ora-sound.com/

Multi-driver headphones
Wieslaw Woszczyk
15h00-15h20

Typical headphone uses a single full-range driver per side. However, multi-driver approaches have been considered, for a variety of reasons, including with added microphones. Some of these choices will be reviewed.

A measurement-based approach in determining the sound quality of headphones
Sam Vafaei
15h20-15h40

Roughly speaking, there are three types of headphone reviews available online: Subjective reviews, subjective reviews with measurements, and objective reviews. There are advantages and disadvantages to each approach, but at rtings.com we have decided to have a purely objective approach to Sound Quality for its repeatability, scalability, consistency, and accuracy. Over the past year we have been developing a method for objectively measuring, scoring, and ranking headphones and for that we have purchased more than 120 headphones and have performed extensive measurements on all them. Through this process we have encountered 3 main obstacles in making sense of headphones measurements and they are: Inconsistent and unreliable readings of the bass range, inconsistent and unreliable readings of the treble range, and the problem of interpretation of the results.

In this presentation I would like to discuss the main issues we have encountered in using measurements to predict the Sound Quality of headphones, and will also offer some solutions we have been attempting in order to minimize these problems. Our solutions range from averaging multiple measurements, measuring some aspects of the headphones on human subjects, to even coming up with experimental ways to tests some more difficult-to-measure aspects of headphones Sound Quality.

EERS™: A device for the connected protected IOT worker
Mylène Landry, Nick Laperle
15h40-16h00

Concerned about workers' hearing safety, EERS has developed, in partnership with its auditory research partner CRITIAS, a "bionic ear", which is adapted to each worker, blocks noise passively and uses de-noising algorithms which allow communication between workers and transmits all the monitoring data to the cloud because it is also a connected device (IoT). The device platform, dubbed Auditory Research Platform (ARP) uses a dedicated hardware circuit with Digital Signal Processor, Micro-controller and I/O's and is available for many other in-ear R&D initiatives, some of which will be covered in this talk.