# Petralex: A multiplatform hearing aid application for real-life communications and listening to digital audio

*Elias Azarov, Maxim Vashkevich, Nick Petrovsky, Denis Likhachov, Alexander Petrovsky*
Computer Engineering Department of Belarusian State University of Informatics and Radioelectronics
Minsk, Belarus

## I. Short description of the proposers

**Azarov Elias** is an associate professor at computer engineering department of Belarusian State University of Informatics and Radioelectronics – BSUIR, Minsk Belarus. His research interests include digital audio and speech processing, sound perception and speech production modeling.

**Vashkevich Maxim** is an associate professor at computer engineering department of Belarusian State University of Informatics and Radioelectronics – BSUIR. His research interests include hearing aid design, fast time-frequency transform algorithms. He received II Award in the competition for young scientists for the best paper for contribution "High-accuracy implementation of fast DCT algorithms based on algebraic integer encoding" in International Conference on Signals and Electronic Systems (Wroclaw, Poland, September 18-21, 2012). He also received a scholarship of the President of the Republic of Belarus (2012).

**Petrovsky Nick** is an assistant lecturer at computer engineering department of Belarusian State University of Informatics and Radioelectronics – BSUIR, Minsk Belarus. His research interests include digital signal processing and multimedia application design for mobile devices.

**Likhachov Denis** is an associate professor at computer engineering department of Belarusian State University of Informatics and Radioelectronics – BSUIR, Minsk Belarus. His research interests include digital audio and speech coding, design of real-time digital signal processing systems.

**Petrovsky Alexander** is a professor and head of computer engineering department at Belarusian State University of Informatics and Radioelectronics – BSUIR, Minsk Belarus. His research interests include digital audio, speech and image processing. His research team focuses on acoustic signal processing, such as speech and audio coding, noise reduction and acoustic echo cancellation, robust speech recognition, and optimization of dedicated and reconfigurable architectures computation intensive algorithms, arithmetic circuits, and algorithm-architecture co-design for digital signal processing and communication.

## II. Demo details

### A. *Purpose of the demo and implementation outline*

The demo presents a hearing aid software implementation for mobile multimedia platforms (smartphones) and personal computers. We designed a special low latency signal processing scheme which performs correction of sensorineural hearing loss. The scheme also compensates flaws of playback equipment providing attenuation of hearing fatigability for long listening or communications sessions.

Hearing loss is one of the actual problems in modern society. According to the World Health Organization, about 360 millions suffer from moderate to severe hearing loss and the number is expected to increase for 30% by 2020 [1]. Considering that, a software hearing aid, compatible with widely distributed multimedia devices (such as smartphones and personal computers) might have a significant social impact.

According to use conditions we designed two versions: a mobile version for real-life communications, implemented on a smartphone and a fixed version for VoIP (voice over IP) communications and digital audio listening, implemented on a personal computer.

A pocket smartphone-based hearing aid has the following benefits (figure 1):

– large-size controls for people with limited motor functions;
– it is easy to implement binaural processing;
– a possibility to use different headsets according to user preference;
– reduced acoustic feedback effect due to a large distance between microphone and speaker;
– a larger power resource allows using sophisticated processing algorithms and high sampling rate;
– applying hearing aid for audio recordings, audiobooks and other digital media;
– in ordinary cases personal setup and adjustment of the aid does not require special equipment and can be successfully performed by the user;
– a smartphone does not look like a hearing aid, so its usage is psychologically more comfortable;
– for smartphone owners it is not required to buy and wear an additional device;

The presented smartphone solution (Petralex hearing aid) is designed as a software application integrated into audio system of the device – figure 2. The audiometry procedure required to adjust parameters of the hearing aid is made using interactive hearing test.

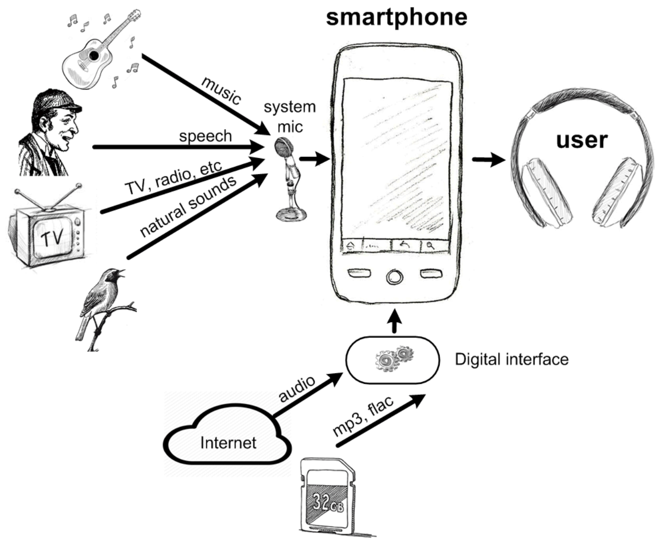


Fig. 1. Pocket hearing aid based on a smartphone

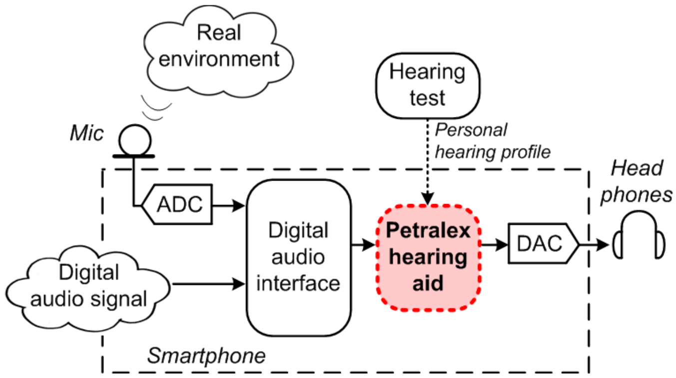


Fig. 2. Designed software integrated into smartphone system

Unlike a smartphone, which can be used in real-life communications, hearing aid on a personal computer pursues different objects which are listed below (figure 3):

– VoIP communications (Skype);
– listening to digital content (audio, movies, audiobooks);
– electronic learning;
– improved hearing tolerance and reducing fatigue for long listening sessions (due to attenuation of excessive sound pressure);

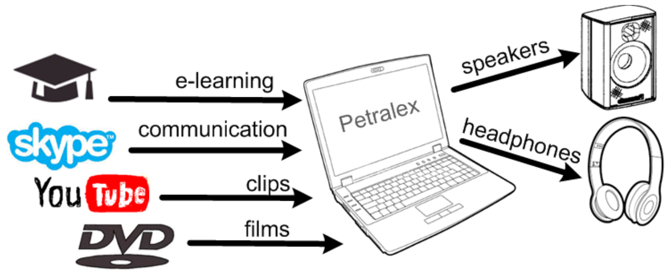


Fig. 3. Hearing aid based on a personal computer

The presented PC solution (Petralex for Windows) is designed as an application with dedicated audio driver (Petralex Virtual Speaker) integrated into audio system– figure 4. The driver creates MS VAD (Microsoft Virtual Audio Device) that establishes desired route of stereo audio stream.

### *B. Build in audiometry and prescription formulas*

Audiometry procedure provides the main characteristics of person's hearing. The procedure consists of user responses to tonal signals and calculation of individual hearing threshold levels (HTL). We use the following frequencies of the tone signals: 125, 250, 500, 1000, 2000, 4000, 6000, 8000Hz. The tones are generated with increasing amplitude from the lowest to the highest over a period of 15 seconds. Since HTLs are measured in situ the values include amplitude-frequency characteristic of the playback equipment.

We implemented the most popular prescription formulas for target gain calculation: Berger [2], POGO (Prescription of gain and output) [3], NAL-R (National Acoustic Laboratories, Australia) [4], and our own original formula intended for lite hearing loss [5].

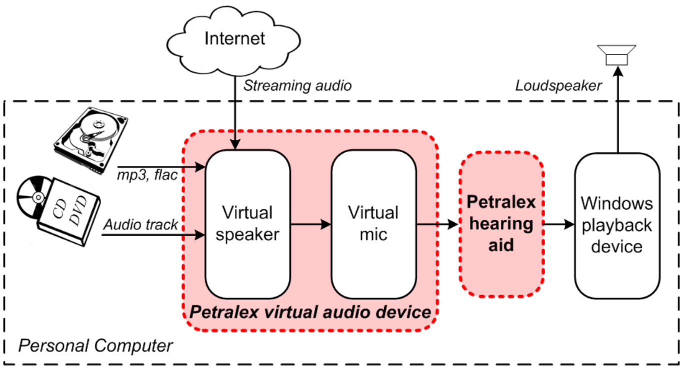


Fig. 4. Designed software integrated into audio system of a personal computer

### *C. Recruitment compensation*

It is known that cochlea of a normal ear performs amplification of quiet sounds up to 50–60 dB [6]. In case of severe hearing loss this ability is degraded and a dynamic compression is required with ratio 2,5:1. We use a wide-band compression scheme that calculates output gains according to input energy of the sound.

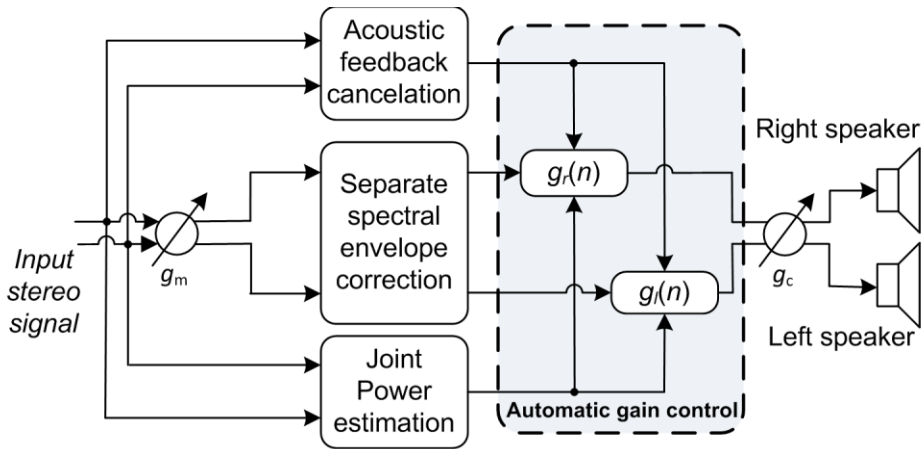


Fig. 5. Implemented signal processing scheme

*D. Signal processing scheme*

We designed a low-latency binaural processing scheme – figure 5. The scheme incorporates amplitude spectrum correction according to measured HTLs, dynamic range compression and acoustic feedback cancellation.

The scheme performs wideband amplitude spectrum shaping using filters with finite impulse responses (FIR). The frequency response of the filter is formed using measured HTL levels. In order to control overall volume of the system the user can adjust either microphone sensitivity $g_m$ or output gain $g_c$. Gain coefficients $g_{l,r}$ are calculated automatically according to compression settings. The scheme operates in real-time and introduces 5ms inherent delay. Depending on operating system and hardware the delay is additionally increased for 10 to 50ms.

*E. What will be shown*

1) Hearing aid based on mobile platform in two versions: for real-life speech communication (Petrlaex hearing aid) and for music listening (Petralex music/radio) both implemented on iPhone (iPad). The user interface of Petralex hearing aid is shown in figure 6.

2) Hearing aid on a personal computer (Petralex for Windows) which is implemented as a virtual device and can be applied for processing of any audio content including real-time Skype communications, music and movie playback etc. Graphical user interface of Petralex for Windows is shown in figure 7.

## III. Demo Experience

The presentation uses an iPhone (iPad) for mobile version demonstration and a laptop for fixed PC version. Both versions are self-sufficient and used separately. An interactive user interface is designed for each application considering its operation conditions. Any person from the public can perform the hearing test and apply digital processing algorithm (using personal hearing profile) for listening some prerecorded audio content or for a live communication via microphone.

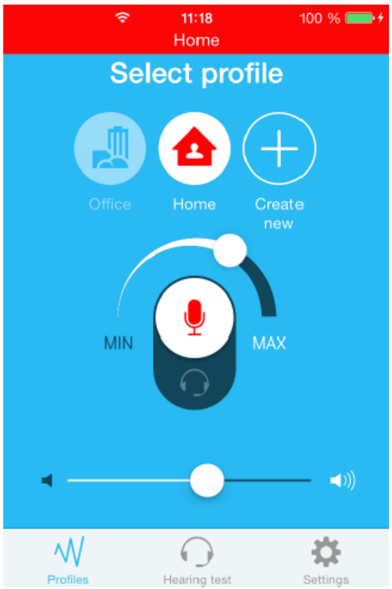


Fig. 6. Petralex hearing aid: user interface for iPhone


Fig. 7. Petralex hearing aid: user interface for PC

## IV. Demo Technical Requirements

There are no special technical requirements. However, it is desirable to have quiet conditions for performing hearing tests.

## V. ACKNOWLEDGEMENTS

The authors are grateful to the ITForYou company for support. This work was also supported by Belarusian Republican Foundation for Fundamental Research (grant No F14MV-014).

## VI. REFERENCES

[1] Deafness and hearing loss. Fact sheet N°300. World Health Organization. – 2013.( http://www.who.int/mediacentre/factsheets/fs300/en/).

[2] K.W. Berger, E.N. Hagberg, and R.L. Rane "Determining hearing aid gain," Hearing Instruments. No. 30, 1980, pp. 26–44.

[3] G.A. McCandless, P.E. Lyregaard "Prescription of gain/output (POGO) for hearing aids," Hearing Instruments. No. 34, 1983, pp. 16–21.

[4] D. Byrne, H. Dillon "The national acoustic laboratories (NAL) new procedure for selecting the gain and frequency response of a hearing aid," Ear and Hearing. No. 7, 1986, pp. 257–265.

[5] E. Azarov, M. Vashkevich, V. Herasimovich, and A. Petrovsky, "General-Purpose Listening Enhancement Based on Subband Non-Linear Amplification with Psychoacoustic Criterion," 138 AES Convention paper 9265, Warsaw, Poland, 2015. – 10 p.

[6] A. Vonlanthen, H. Arndt, "Hearing Instrument Technology for the Hearing Health Care Professional," Thomson Delmar Learning, Clifton Park, NY, 2006.