Artificial Intelligence and Hearing Aids

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Background

- According to World Health Organization hearing report (2021), globally more than 1.5 billion individuals experience hearing loss (HL) during lifetime. Hearing aids (HAs) are viewed as effective tools to mitigate unfriendly effects caused by HL. But typical HA algorithms still rely heavily on degree of HL to restore hearing, which is successful in restoring faint sounds, but lacks treatments for complex sensorineural deficits. The general signal processing scheme of an analog HA and a modern digital HA is shown in Figure 1.

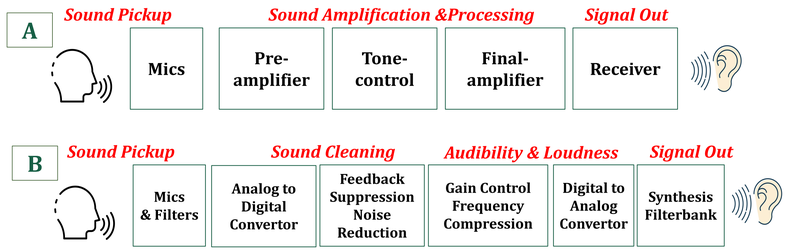

Figure 1. signal processing scheme of a typical analog hearing aid (A) and a digital hearing aid (B)

- Three revolutions in HAs are occurring through signal processing technologies during the past several decades from nonlinear amplification, digital signal processing, to wireless. Artificial intelligence (AI) has received significant attention recently and has been applied to multiple fields. It is said that machine intelligence is the next revolution in HA(Zhang et al., 2016).
- Recent research regarding AI in HA has included: machine learning (ML), deep learning (DL) and neural network (NN) as shown in Figure 2. These processes are designed to mimic the complex neural mechanisms such as nonlinear transmission of the sounds.

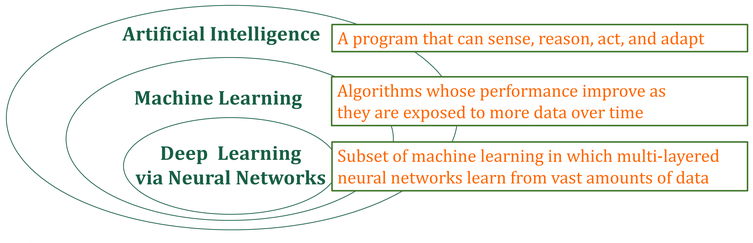

Figure 2. Artificial intelligence and other advanced technologies.
Source: https://towardsdatascience.com/cousins-of-artificial-intelligence-dda4edc27b55

Purpose

The purpose was to complete a literature review of AI applied in HA technologies.

Methods

Applications of AI technologies related to HAs were identified through professional research databases including journals, conferences proceedings and other web-based sources. Inclusion criteria for articles were peer-reviewed, English writing, and published between 2017 and Oct. 2022.

Data Sources: PubMed, Speech, Language and Hearing POWERSEARCH, Linguistics & Language Behavior Abstracts, Google Scholar

Keywords: (machine learning or artificial intelligence or deep learning or neural network) AND hearing aid. All keywords were in [Title/Abstract]

Results

Search results indicated an increasing attention over the past 26 years

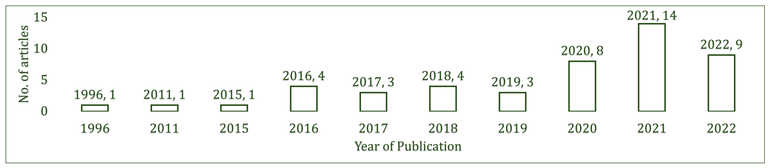

Figure 3. Publications since 1996 using the above-mentioned keywords from PubMed.

Representative Articles of AI applications to fit HAs

Author & Publish year	Publication	Methods	Result
Belitz et al., 2021	JASA Express Letters	ML clustering methods (Birch, Ward, and k-means)	Reduced time-to-convergence to improve HA fitting and acceptance
Hodgetts et al., 2021	Applied Sciences	Trained representative voice samples from Season 1 of Modern Family by Convolutional NN (CNN)	High accuracy. Familiar voice features can improve hearing performance
Tu et al., 2021	arXiv	A differentiable HL model is proposed and used to optimize fittings with back-propagation.	Optimized custom fittings was better than general prescriptive fittings
Ni et al., 2022	Sensors	An ML-based personalization fitting was carried out based on the user preference model within the framework of maximum likelihood inverse reinforcement learning.	The personalized adaptive dynamic range optimization (ADRO) was preferred over the standard ADRO.
Drakopoulos & Verhulst, 2022	arXiv	Used a differentiable deep NN (DNN) framework that can train DNN-based HA models based on biophysical auditory-processing differences between normal-hearing and hearing-impaired models.	Auditory-processing restoration was possible for all considered HL cases, with outer-hair-cell loss proving easier to compensate than cochlear-synaptopathy impairment.

Representative Articles of AI applications to Speech Enhancement (SE):

Author & Publish year	Publication	Methods	Result
Andersen et al., 2021	Seminars in Hearing	Combine an MVDR beamformer with a postfilter, data trained by DL	Enhanced speech intelligibility in noise and reduced listening effort.
Bhat et al., 2019	IEEE access	An SE technique based on multi-objective learning CNN was implemented on a smartphone to perform real-time SE, working as an assistive tool to HA.	There were significant improvements over the state-of-the-art techniques and reflect the usability of the developed SE application in noisy environments.
Bramsløw et al., 2018	The Journal of the Acoustical Society of America	The competing voices benefit of a DNN-based stream segregation enhancement algorithm was tested on listeners with HL. A mixture of two voices was separated using a DNN and presented to the two ears as individual streams and tested for word score.	DNNs have a large potential for improving stream segregation and speech intelligibility in difficult scenarios with two equally important targets without any prior selection of a primary target stream for listeners with HL.
Castro Martinez et al., 2022	Computer Speech & Language	A speech intelligibility model based on automatic speech recognition, combining phoneme probabilities from DNN, was used to estimate the word error rate from these probabilities.	The proposed model performed almost as well as the label-based model and produced more accurate predictions than the baseline models.
Borgström et al., 2021	Neural Networks	The Binaural Enhancement via Attention Masking Network system was designed through an end-to-end neural network architecture based on self-attention.	Subjective testing shows an improvement in speech intelligibility across a range of noise levels, for signals with artificially added head-related transfer functions and background noise.
Keshavarzi et al., 2018	Trends in Hearing	The potential benefits of using a deep RNN for reducing wind noise were assessed compared with high-pass filtering (HPF).	Processing using the RNN was significantly preferred over no processing by both subject groups for both subjective intelligibility and sound quality,

Results continued

Applications of AI in Six HA manufacturers

Figure 4. Examples of artificial intelligence applications in main hearing aid manufacturers

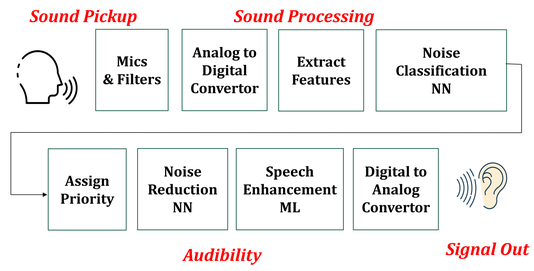

Figure 5. Signal processing scheme of a digital HA with Artificial Intelligent processing (adapted from Zhao & Liu, 2021)

Conclusion

- AI applied to HA technologies is still in rapidly growing, which is highly dependent on the development of digital processing in wearable devices and sensitive sensors (e.g., health tracking).
- The benefits of AI-based HAs are mainly present in the noise reduction and speech enhancement. For situations without much noise or the noise issue was properly solved (e.g., using remote microphone technologies), AI may not show additional benefits.

References

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