Computational neuroimaging of real-life listening

Chapter 6

Knowledge valorization

Introduction

Our daily interactions with the world depend on how we perceive the sounds from the many sources around us. The human brain is capable to perform complex tasks with small effort, such as distinguishing a friend's voice in a crowded café or listening to a melody in a noisy environment. Beyond communication, hearing has a primary role also for our safety as particular sounds can be used to call for attention (a passing car horn honking) or to announce danger (a fire alarm). The quality of our lives is deeply related to sound perception and, thus, auditory research plays an essential role in improving the daily living conditions.

Valorization

Around 5% of the population worldwide is affected by disabling hearing loss, with serious social, psychological and economic impact on society (World Health Organization, 2018). Although the majority of the affected people can benefit from hearing aids, only a small percentage uses them (20% in the USA according to the National Institute of Health), mainly due to the low performance in noisy environments and poor speech intelligibility (Lesica, 2018). Amplifying the incoming sound and/or performing the selective filtering of specific frequency bands is not sufficient to overcome such limitations, as this enhances the background noise and the competing sound sources.

In this context, the studies described in the present thesis provide new insights into the neural mechanisms underlying sound processing. Understanding the complex transformations that sounds undergo through the ascending auditory pathway can help in improving the performances of hearing aids, filling the gap between peripheral and cognitive functions.

Hearing devices, in fact, may be complemented by operations capable to replace the lost physiological functions, processing only the acoustic/perceptual features relevant for a specific task (i.e. feature extraction/reduction, pattern analysis and advanced machine-learning methods). This means that the results presented here can contribute to develop real-time brain-inspired and brain-controlled hearing aids optimized for noisy environments, with the possibility to adapt and personalize the devices according to the individual needs of the impaired people.

The results and methodological approaches described in the present thesis may be additionally used to improve the performance of the so-called "smart" alarm devices employed for house safety and surveillance. Such systems are capable to analyze the environmental acoustic scene and discriminate unexpected sounds from the usual ones (i.e. those produced by Cocoon and Audio Analytic). This technology is based on advanced machine-learning techniques that need large datasets including sounds of different categories in order to reach high levels of performance.

This is the fundamental approach of the advanced speech recognition systems developed by the world leading companies, such as Google, Apple, Microsoft and Amazon. Nowadays, in fact, the voice-based technology is likely to become the most common way to communicate with electronic devices (Dumaine, 2018). The development of artificial systems capable to execute specific tasks upon vocal requests has the remarkable potential to support people with physical disabilities, enabling them to use computers without effort (as the Dragon Speech Recognition Software from Nuance).

In this context, replicating the performances of the human brain (especially in case of concurrent sounds and/or background noise) remains a big challenge, although the recent development of complex models integrating multi-sensory information (i.e. audio-visual) and trained over large datasets provided new methodological advances (Ephrat et al., 2018).

Conclusions

The research described in the present thesis may find several potential applications that have the aim to support the quality of life of hearing and physically impaired people. Importantly, it contributes to the development of sound-controlled artificial systems, which represents one of the most important growing industries of our time.

References

Dumaine B (2018). *It Might Get Loud: Inside Silicon Valley's Battle to Own Voice Tech.* Retrieved from: http://fortune.com/longform/amazon-google-apple-voice-recognition.

Ephrat A, Mosseri I, Lang O, Dekel T, Wilson K, Hassidim A, Freeman WT, and Rubinstein M (2018). Looking to Listen at the Cocktail Party: A Speaker-independent Audio-visual Model for Speech Separation. *ACM Trans Graph* 37(4). DOI: 10.1145/3197517.3201357.

Lesica NA (2018). Why Do Hearing Aids Fail to Restore Normal Auditory Perception? *Trends Neurosci.* DOI: 10.1016/j.tins.2018.01.008.

National Institute of Health (2018). *Fact sheets, Hearing Aids.* Retrieved from: https://report.nih.gov/nihfactsheets/viewfactsheet.aspx?csid=95.

World Health Organization (2018). *Fact sheets, Deafness and hearing loss.* Retrieved from: https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss.