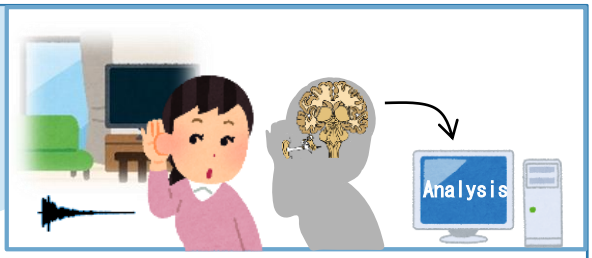
24 Understanding human hearing with AI

- Analyzing auditory neural mechanisms with machine learning -

Abstract

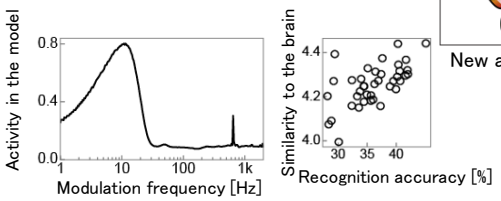
In our daily life, we encounter sounds with highly complex structure, which are processed by our ears and brain containing a network of numerous neurons. We are trying to understand the complex relationship between sound and the ear and the brain with a help of machine learning technique based on which current “artificial intelligence” is built. In typical cognitive neuroscience studies with a hypothesis-testing paradigm, research outcomes are highly dependent on pre-designed hypothesis. We employed machine learning techniques for extracting relationships in the complex data, and are gaining insights of auditory mechanisms without relying on strong hypothesis. Such a paradigm may enable us to find and propose new hypotheses that have been overlooked by past researches and lead us to true understanding of neural mechanisms. Also, such techniques may be helpful for designing sounds taking individual hearing abilities into consideration including elders and people with hearing deficits.

Sound contains various information of sound source objects and environments. Our ears and brain process the information with complex neural mechanisms. By applying machine learning methods used in artificial intelligence to experimental data, we have revealed essential mechanisms of auditory representation of sounds that has not been explained previously.



Temporal modulation [1]

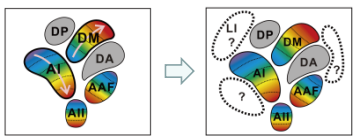
- Has the representation of temporal variation been evolved for sound recognition?
- Neurons in the auditory system exhibit tuning to temporal variation depending on the brain regions.
- A neural network trained for sound recognition exhibits similar tuning.

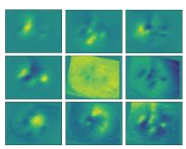


Data-driven analysis [2]

- How are auditory brain regions divided? What are their characteristics?
- Brain regions are divided by machine learning from the recorded activities in mice brains.

(Collaboration with Niigata University.)

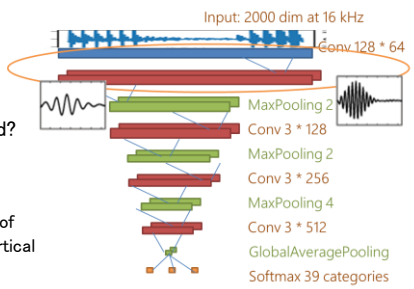




Nine eigen-activations of auditory cortical regions.

Frequency tuning [3]

- Why do auditory nerves tune to sound frequency?
- Supervised deep learning explains the tuning in presence of reverberation
- The frequency tuning may be optimal for sound recognition in the natural environment.



New approaches for understanding hearing mechanisms with artificial intelligence.

References

[1] T. Koumura, H. Terashima, S. Furukawa, “Representation of amplitude modulation in a deep neural network optimized for sound classification,” in Proc. 41st Annual Midwinter Meeting of the Association for Research in Otolaryngology, 2018.

[2] H. Terashima, H. Tsukano, S. Furukawa, “An attempt to analyze brain structure in mice using natural sound stimuli,” in Proc. Winter Workshop of Mechanism of Brain and Mind, 2012.

[3] H. Terashima, S. Furukawa, “Reconsidering the efficient coding model of the auditory periphery under reverberations,” in Proc. 41st Annual Midwinter Meeting of the Association for Research in Otolaryngology, 2018.

Contact

Takuya Koumura Sensory Resonance Research Group, Human Information Science Laboratory