Researcher discusses electronic cochlear architecture

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Researchers have developed an architecture and digital implementation of an electronic cochlea with an acoustic fovea and address event representation using field programmable gate arrays. Prof. Andreas Andreou of Johns Hopkins University in the US talks about his group's approach to bio-inspired technology, like the work in this recent paper.

Tell us about your field of research.

Sensory information processing research in my lab at JHU is two pronged. From a science perspective, we aim to understand the fundamental principles of sensory communication, the process that enables humans and animals to interact with the environment. Sensory communication is a closed-loop process, beginning with the sensing and detection of sights, sounds and other stimuli, to processing and cognitive function, which ultimately results in a response of the individual to the perceived stimuli. From a technology perspective, we strive to abstract the knowledge into engineered systems. This is a broad research field that links bi-ology, electrical engineering and computing science, and it is at the heart of what is often called "cognitive neuromorphic engineering" or "bio-inspired systems"

As you can see, my research directly relates to our everyday experience; we are trying to understand how we perceive the world and how our perception guides our actions and interactions within our environment.

What particular applications interest you?

I have always been fascinated about how we see and hear, how our sensory organs transform physical stimuli such as light and sound into electrical and chemical activity in our nervous system, and how our brains process the information leading to human cognition. How can music have such an enormous impact on the state of our mind, and why is a brief view of an art piece in a museum transformed instantly into a story in our mind that tells us something about the artist? Slowly but steadily, scientists are unravelling the mysteries of the brain and the engineering of labs such as ours begins to endow the technologies that we use daily, computers and smart phones, with human-like cognitive capabilities. This is sometimes scary!

What have you reported in your Electronics Letters paper?

We report the first electronic cochlea structure that implements the acoustic fovea region in the horse-shoe bat cochlea. We have also used the engineered system to process micro-Doppler signals from a scaled model of a moth and show how the output for the electronic cochlea compares nicely with traditional spectral analysis of the sound.

A foveated electronic cochlea is a synthetic signal processing system inspired by biological cochleae – intricate electro-mechanical systems that transform sound into electrical activity in our ears. The cochlea structure of all animals analyses sound with a frequency resolution that is spaced logarithmically in the frequency. The horse-shoe bat has an unusual cochlea structure. A small section of the cochlea, near the 80 KHz frequency at which the bat vocalises, exhibits linearly spaced narrow-bandwidth filter characteristics. The high resolution acoustic analysis region in the horse-shoe bat cochlea is analogous to acute vision in the fovea of our eyes, hence the term foveated cochlea. The function of this foveated region is to detect acoustic micro-Doppler signals from flying insects, which are the bat's prey. It is further hypothesised that a fine analysis of the micro-Doppler sound signatures reflected from the beating wings of the insects enables the bats to make adaptive prey-selection decisions on the value of the food, for example the size of the moth and its worthiness for pursuing!

How do you see this field developing?

Neuromorphic and bio-inspired systems are emerging as key technologies to provide the interfaces of modern information processing devices and the internet. Sensing and processing in an effective and energy-efficient manner, as done in the electro-mechanical processing systems of biological cochleae, is a major challenge using only CMOS electronic technologies. Yet, through a deep understanding of biological systems, and by abstracting their operating principles judiciously, not by simply copying, we can strive towards approaching the marvels of heterogeneous integration and structural complexity that we see in biological systems.

What else is your research group working on?

Our group is working on several systems at different levels of abstraction that straddle the interface of science and technology for sensory systems. An exciting technological development is the use of 3D CMOS technology enabling us to engineer structures that exploit the effectiveness and energy efficiency of 3D rep-resentation and wiring. One of the most recent and exciting developments in this direction is the design of an array of electronic rods in 3D CMOS, silicon photoreceptors with single photon sensitivity.

More information: "Acoustic micro-Doppler signal processing with foveated electronic cochlea." *Electronics Letters*, Volume 51, Issue 2, 22 January 2015, page 126. DOI: 10.1049/el.2014.4427 , Print ISSN 0013-5194, Online ISSN 1350-911X

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