Bats lend an ear to sonar engineering

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Researchers have mapped out the diversity of bat ears in a hope to inspire the design of new intuitive methods of manipulating waves with physical shapes, such as SONAR and RADAR.

Published today, Tuesday, 10 May, in IOP Publishing's journal *Bioinspiration & Biomimetics*, the study provides key insights into the variability of the shapes of bat ears that exists between different species, and shows how this variability may affect the functionality of one of the most impressive navigational systems in nature.

Bats are one of a few animal groups that demonstrate biosonar—the ability to generate and emit ultrasonic pulses and gauge the reflections to obtain detailed information on their surroundings.

Bats use biosonar as a way of navigating and hunting for food, however researchers have seen its potential to inspire new ways of engineering where manipulating outgoing or incoming waves with structures is a principal component.

Lead author Professor Rolf Müller, of Virginia Tech, said: "Using physical shapes to manipulate an outgoing or a received wave has application in many areas of engineering. Besides the obvious analogues of SONAR and RADAR, such principles could also find application in biomedical ultrasound, non-destructive testing, wireless communications, and sensory systems for autonomous robots and nodes in sensor networks."

The ear of a bat plays a crucial role in the overall sensing system by acting as a baffle to diffract the incoming waves therefore determining the ear's pattern of sensitivity to direction and frequency.

The researchers, working in a joint research laboratory of Shandong University and Virginia Tech, created 3D computer models of 100 bat pinnae—the visible part of the ear that resides outside of the head—from 59 different species, and transformed the models into cylindrical representations.

The representations were statistically analysed using principal component analysis—a method that has previously been applied to analyse human faces, palms, and ears —and were shown to vary in the opening angle of the pinna, breaks of symmetry between the right and left sides, and changes in width at both the top and bottom.

The researchers also demonstrated how this variability can affect the properties of beamforming—the process by which the incoming signal is diffracted by the shape of the pinna to create a "beampattern" through which the bat sees it environment.

The variability occurs as a result of the evolution of bats whose habitats range from environments with virtually no structures, to those with simple structures (calm water surfaces), to habitats with very complicated structures (dense forests).

The researchers found, for example, that a group of bats that hunts for prey in dense vegetation with trains of long, closely-spaced objects are separated from other bats by the widths of their pinna openings, demonstrating how biodiversity can provide a useful insight into how a general principal can be customised to fit different needs.

Professor Müller continued, "In order for this to happen, the ears of bats must be studied further. An example would be to expand the sample to include more diversity and find more specific relationships between pinna shape and beamforming across different species. Small local shape features that are hard to capture by the present analysis can also have a big impact on the function."

More information: A method for characterizing the biodiversity in bat pinnae as a basis for engineering analysis, Jianguo Ma and Rolf Müller 2011. *Bioinspir. Biomim.* 6 026008
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Abstract
A quantitative analysis of the interspecific variability between beamforming baffle shapes in the biosonar system of bats is presented. The data set analyzed consisted of 100 outer ear (pinna) shapes from at least 59 species. A vector-space representation suitable for principal component analysis (PCA) was constructed by virtue of a transform of the pinna surfaces into cylindrical coordinates. The central axis of the cylindrical transform was found by minimizing a potential function. The shapes were aligned by means of their respective axes and their center of gravity. The average pinna of the sample was a symmetrical, obliquely truncated horn. The first seven eigenvalues accounted already for two-thirds of the variability around the mean, which indicates that most of the biodiversity in the bat pinna can be understood in a more low-dimensional space. The first three principal components show that most of the variability of the bat pinna sample is in terms of opening angle, left–right asymmetry, and selective changes in width at the top or the bottom of the pinna. The beampattern effects of these individual components have been characterized. These insights could be used to design bioinspired beamforming devices from the diversity in biosonar.

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