Towards Deep Evolutionary Reinforcement Learning for Echo-Based Navigation in Complex Natural Environments

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Agenda

- Motivation and Introduction
- Current Work and Results
- Future Work
- Questions and Discussion

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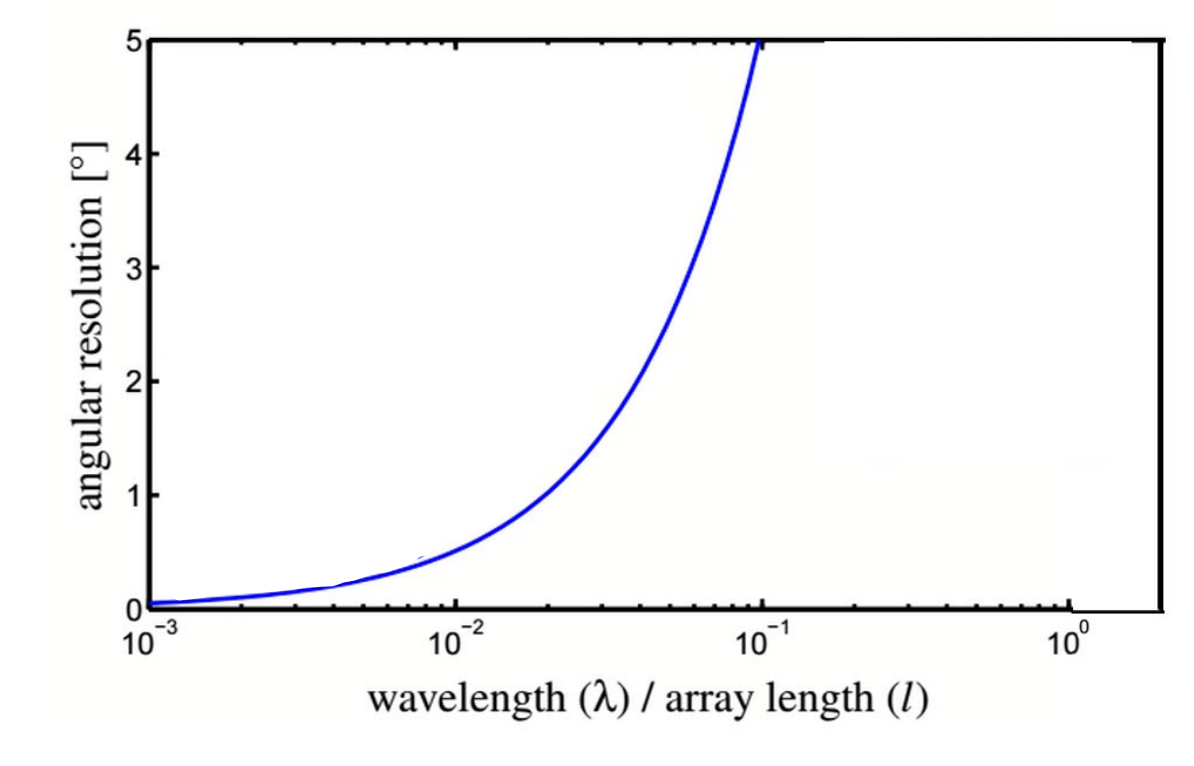
Motivation

- Sonar can be used to explore and navigate in an unknown environment
- Modern sonar design paradigms have performance limitations which make use in miniaturized systems difficult
  - Mostly related to the number of receivers needed in order to obtain a fine angular resolution, particularly useful for direction finding and classification

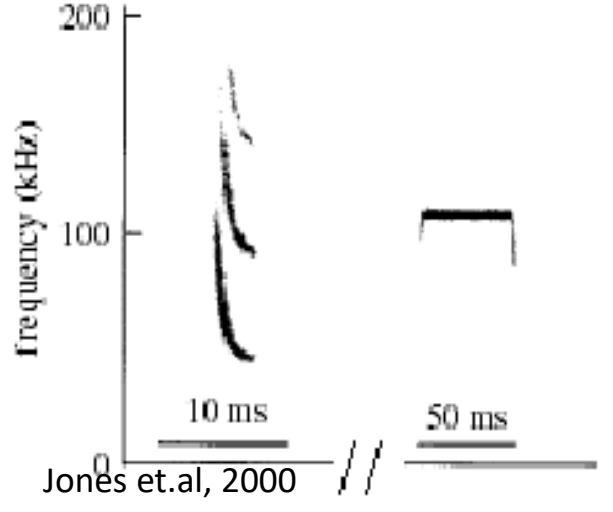


Navigation in Cluttered Environments

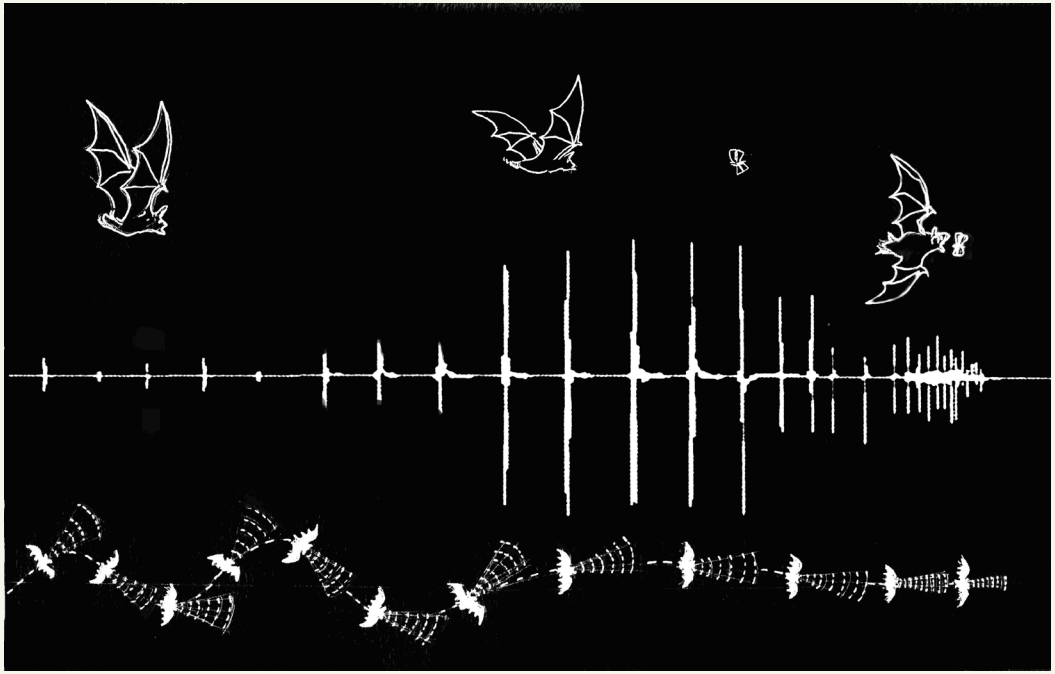
- Conventional approaches to navigation in natural environments include GPS, LiDAR, Radar, and Camera Arrays.
- Air-based sonar sensors pose as a well-suited alternative to these approaches given a high enough angular resolution.
- Bats can overcome the physical limitations of conventional sonar design, while encoding enough sensory information to navigate complex natural environments indicating that operating with such limited data is possible.

Navigation in Cluttered Environments

FM bat CF-FM bat



Jones et.al, 2000



Emission and Reception in Horseshoe Bats

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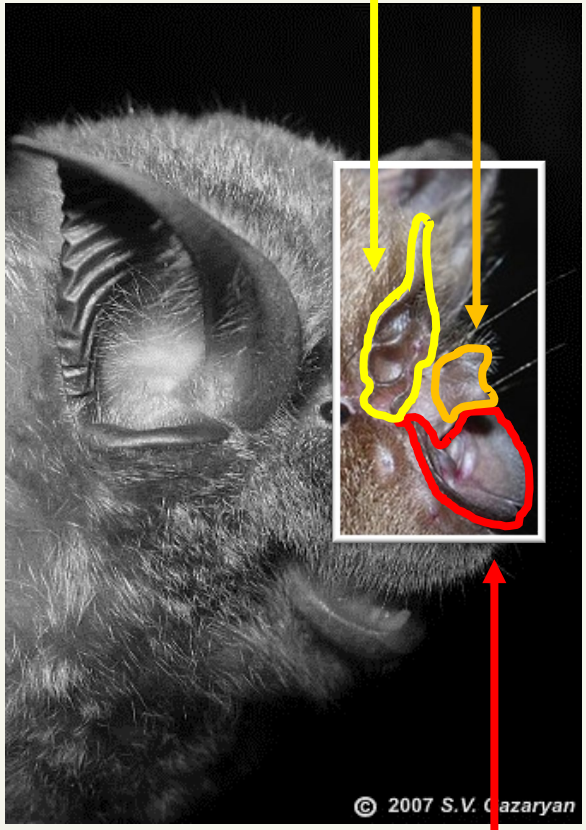
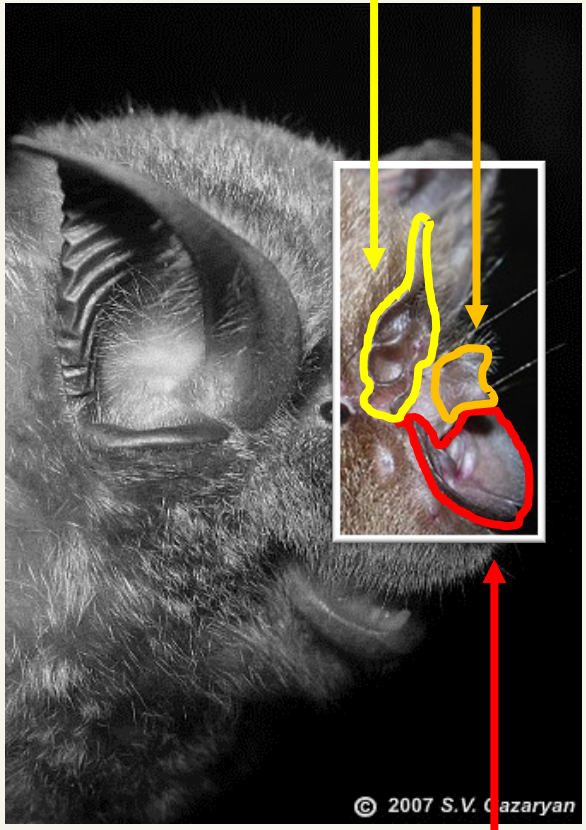
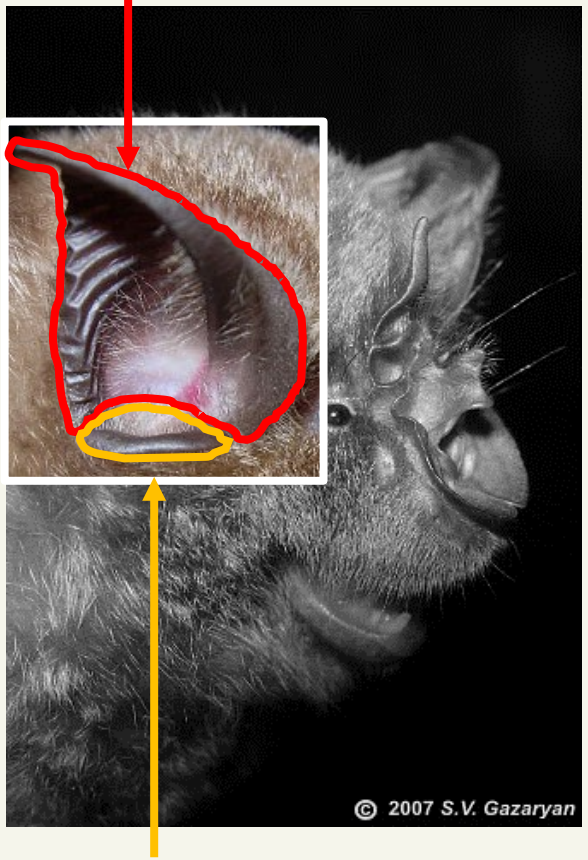


Emission and Reception in Horseshoe Bats





Emission and Reception in Horseshoe Bats

Flying Dynamics in Horseshoe Bats

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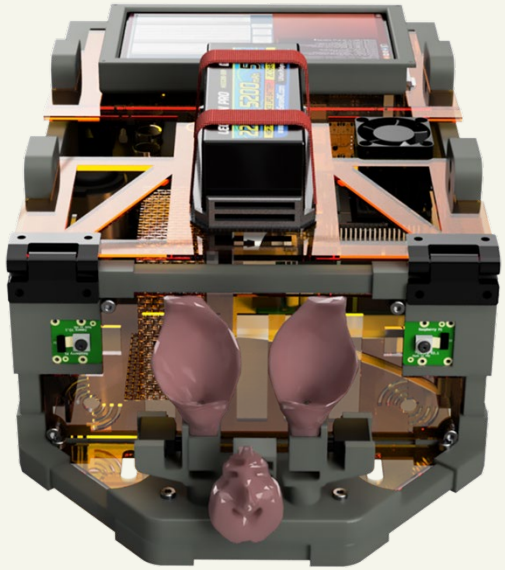
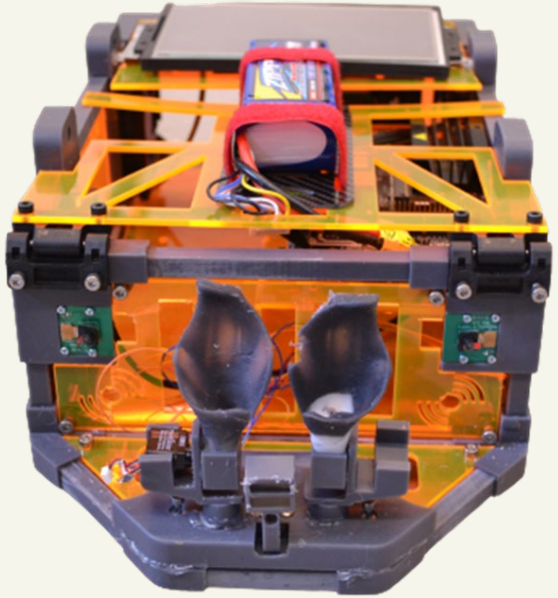
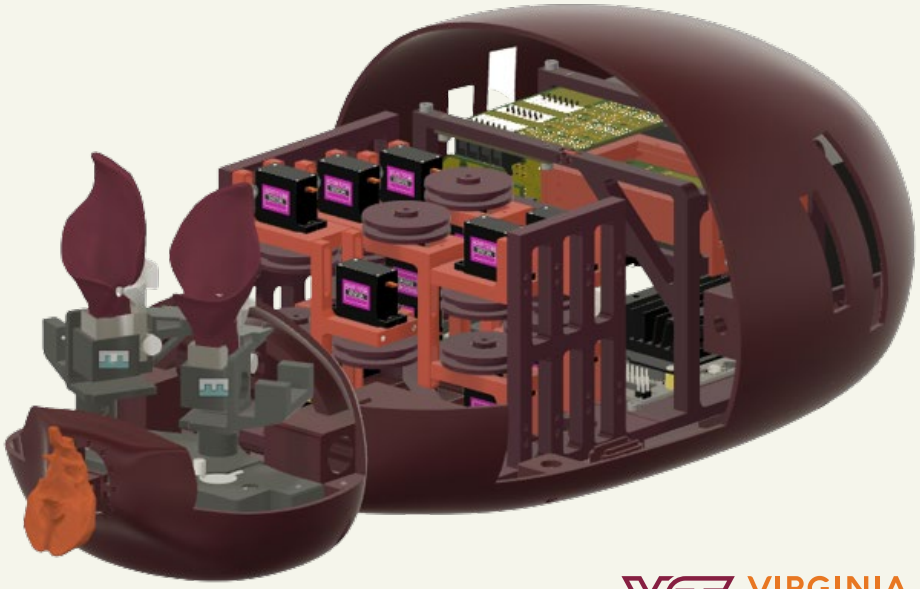
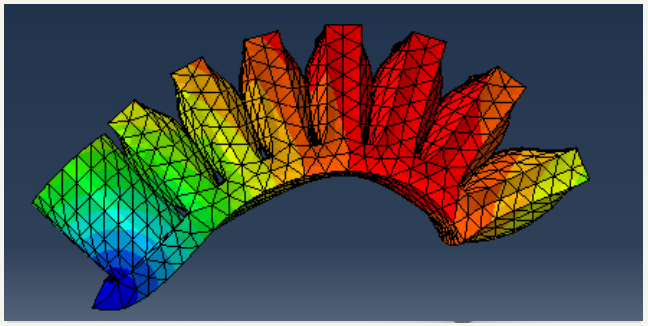
Evolution of a Biomimetic Sonar Head

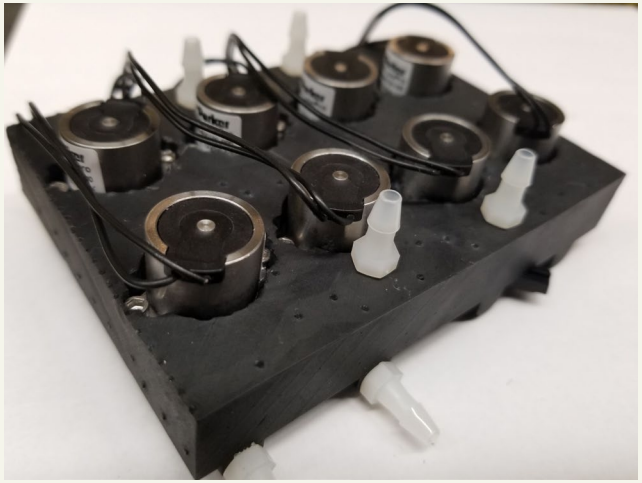


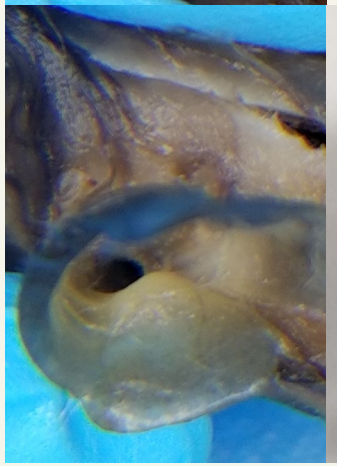




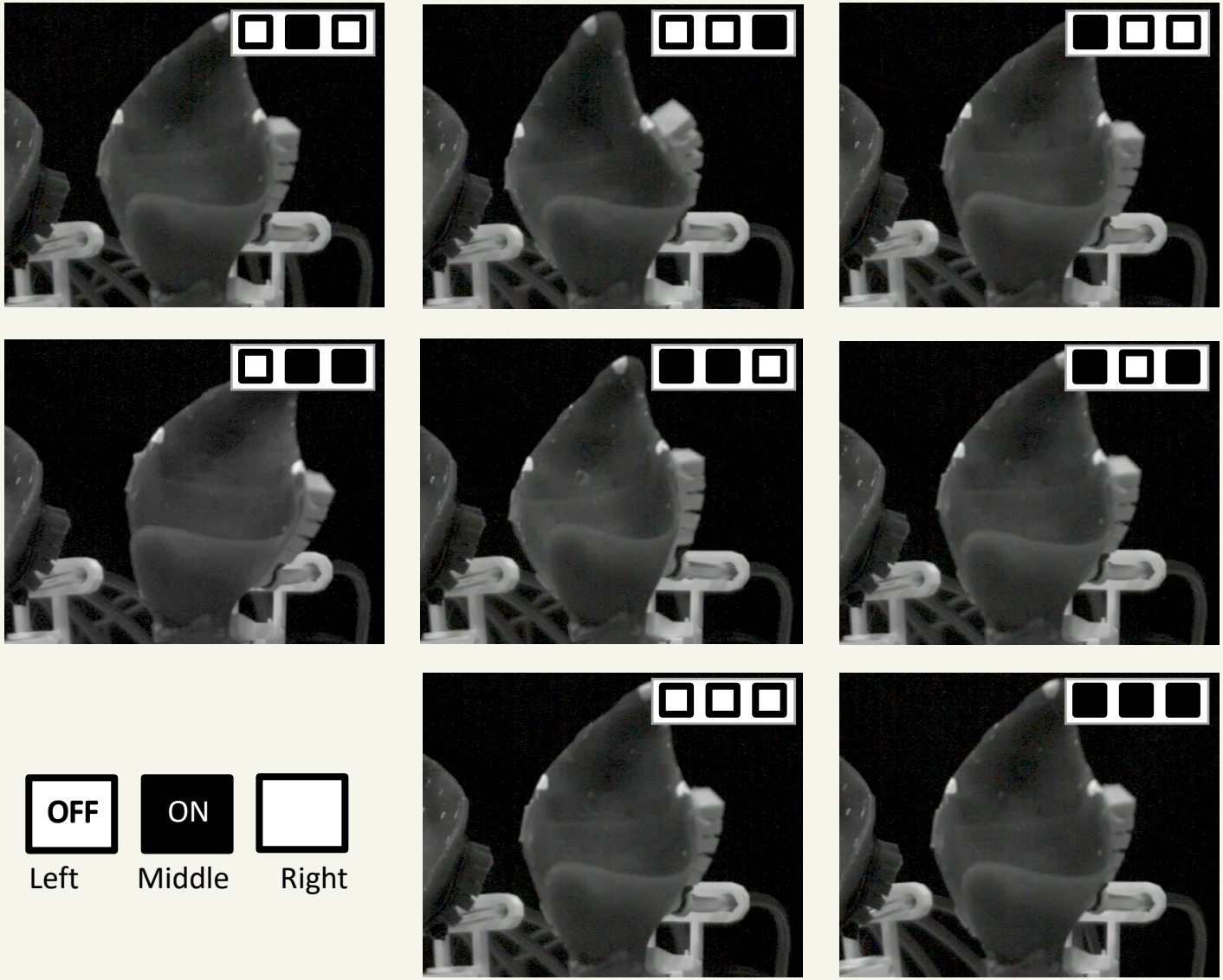
Prior Work: Ear Model & Soft Robotic Actuation



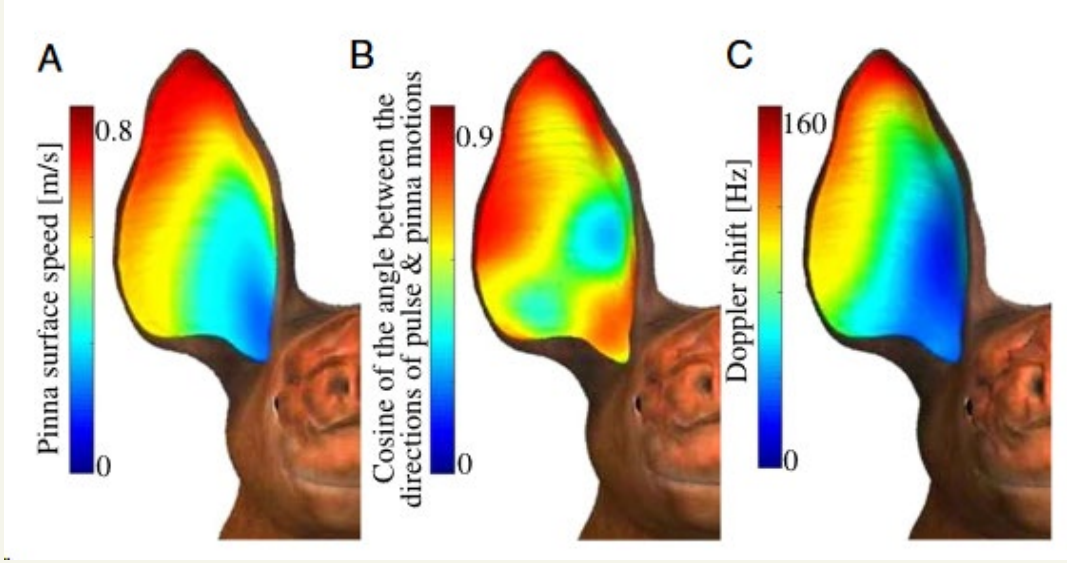


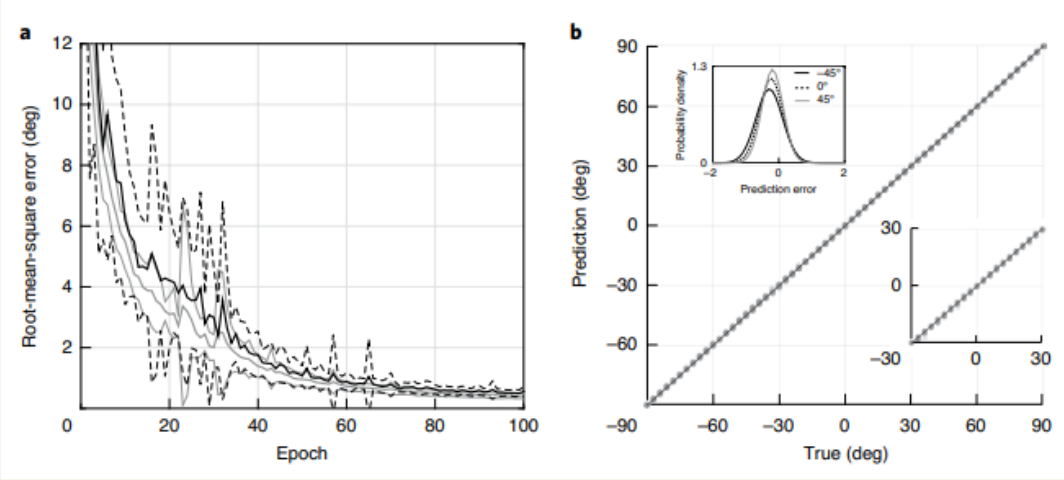


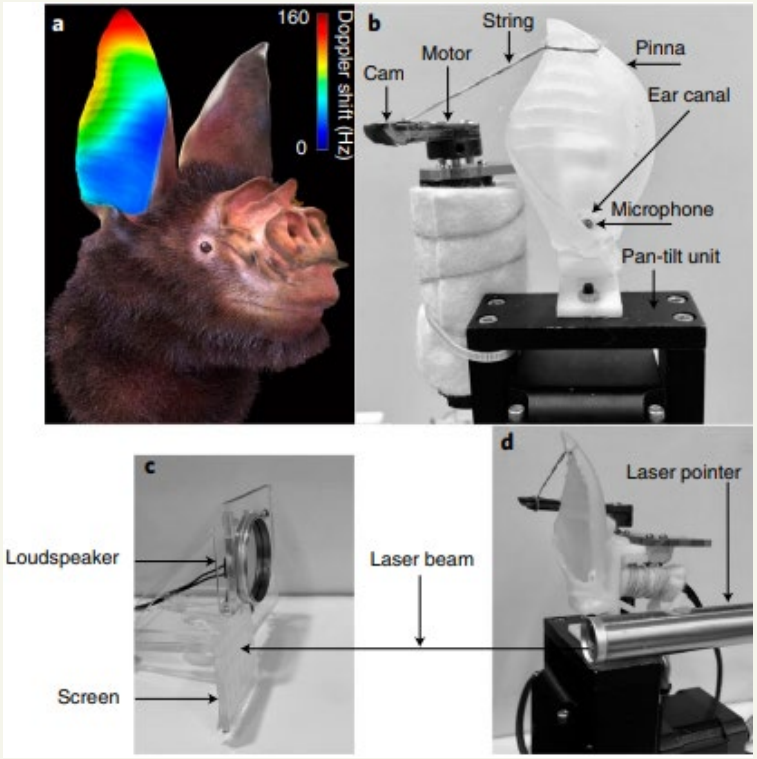
Actuation of Soft Robotic Pneumatic Pinna



Fast Moving Ears Create Informative Dopplers



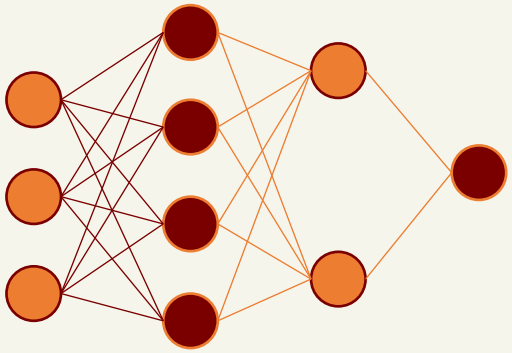


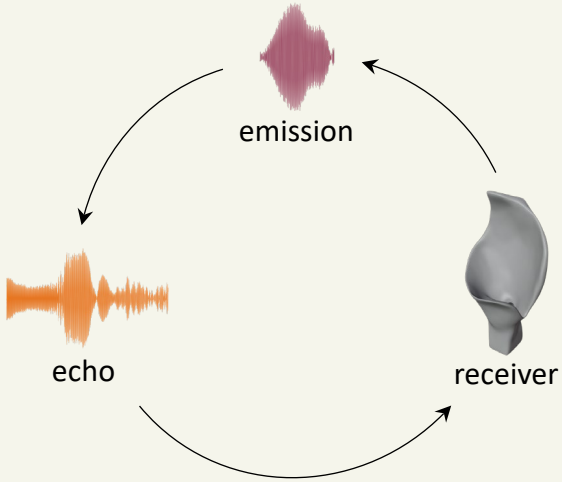


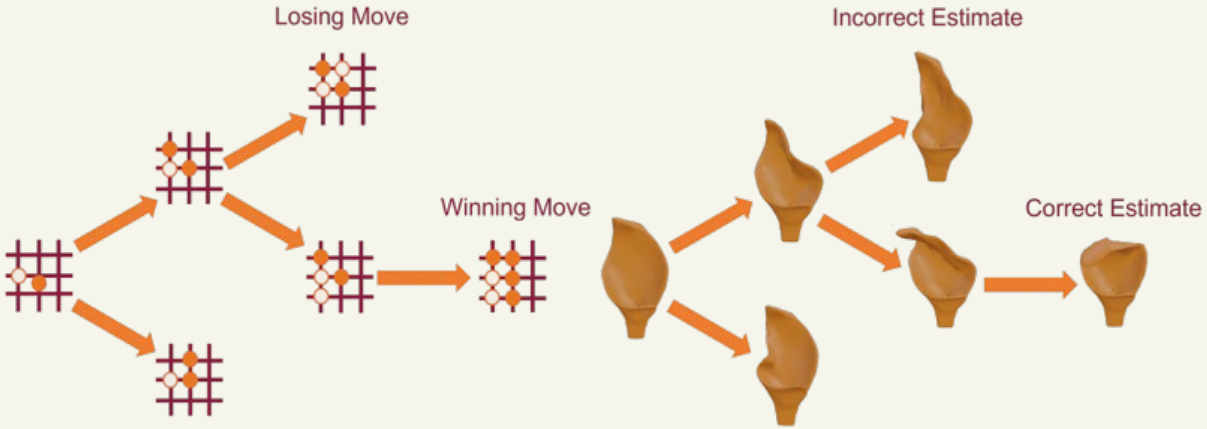
Overall Vision

Useful Parameter(s)

$$\begin{bmatrix} \theta \\ \varphi \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$$

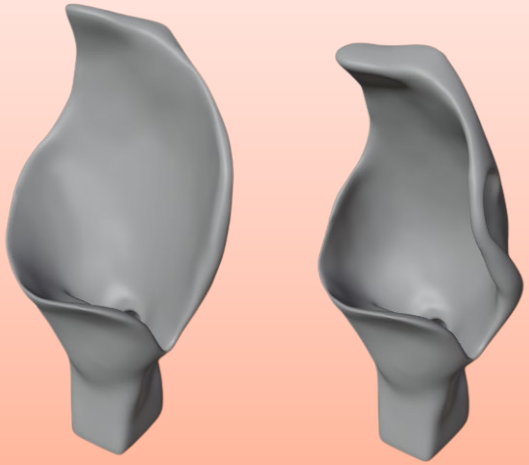






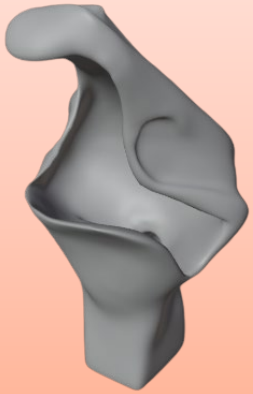
Static Deformation States – All Sets

Dynamic

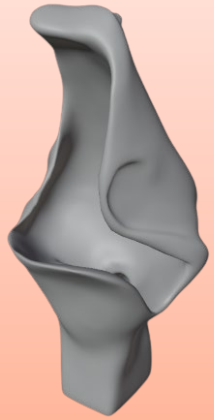


0, 0, 0

5, 5, 5



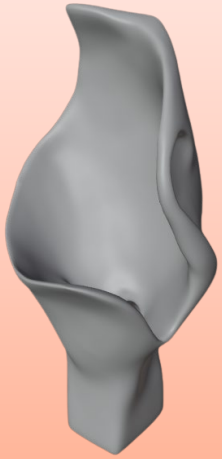
10, 10, 10



10, 5, 10

5, 0, 0

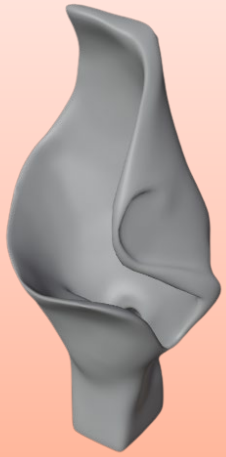
0, 5, 0



0, 0, 5

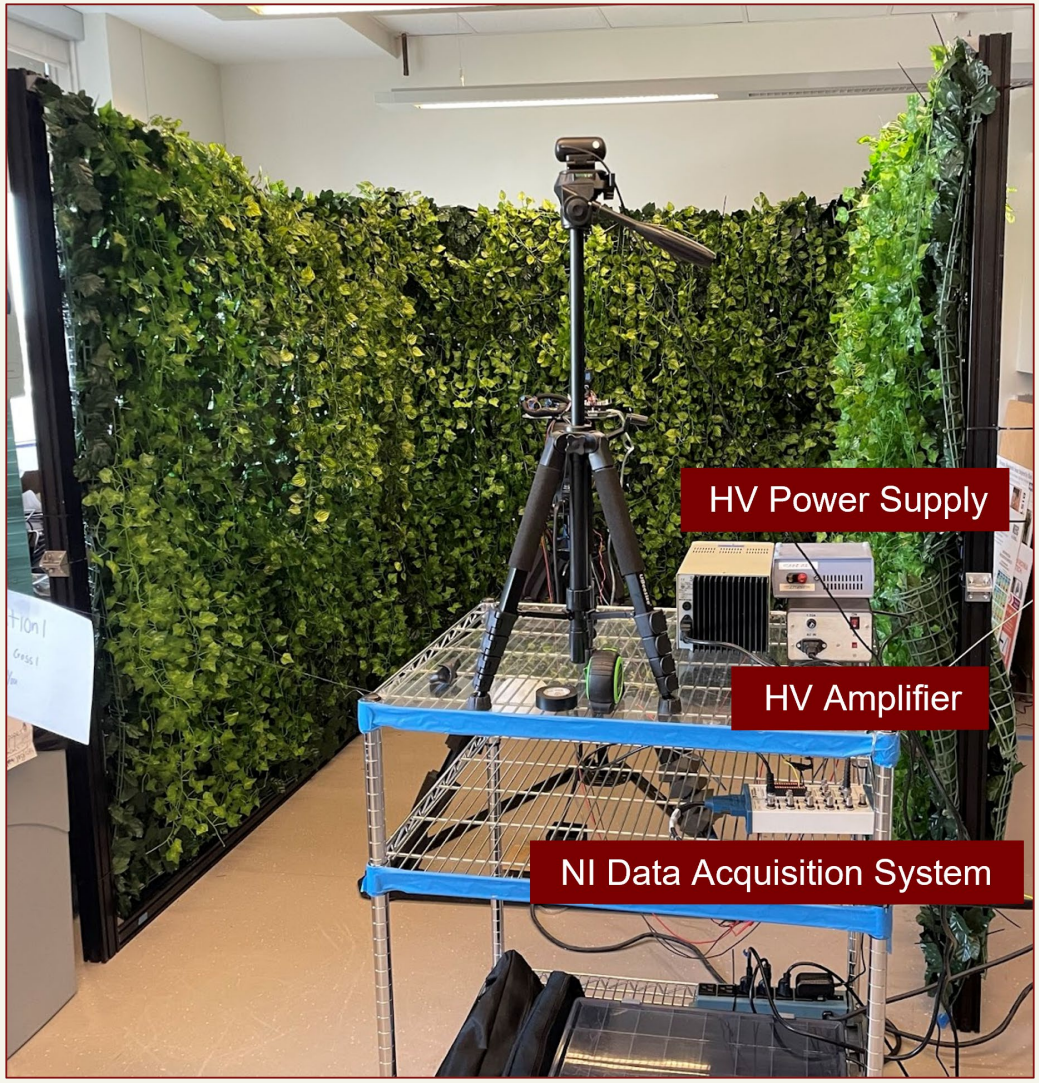
10, 0, 0

0, 10, 0



0, 0, 10

Experimental Lab Setup



Far Field Boundary

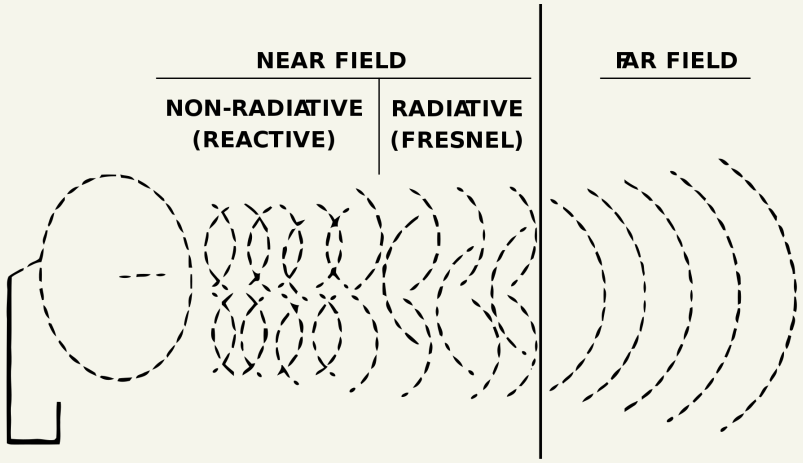
$$d_{100kHz} = \frac{2 * (0.05m)^2}{0.00343\ m} = \sim 1.45\ m$$

$$d_{20kHz} = \frac{2 * (0.05m)^2}{0.01715\ m} = \sim 0.30\ m$$

$$d_{80kHz} = \frac{2 * (0.05m)^2}{0.0042875\ m} = \sim 1.15\ m$$

$$d_{30kHz} = \frac{2 * (0.05m)^2}{0.01143\ m} = \sim 0.43\ m$$

$$\boxed{d_{actual} = \sim \mathbf{1.40\ m}}$$



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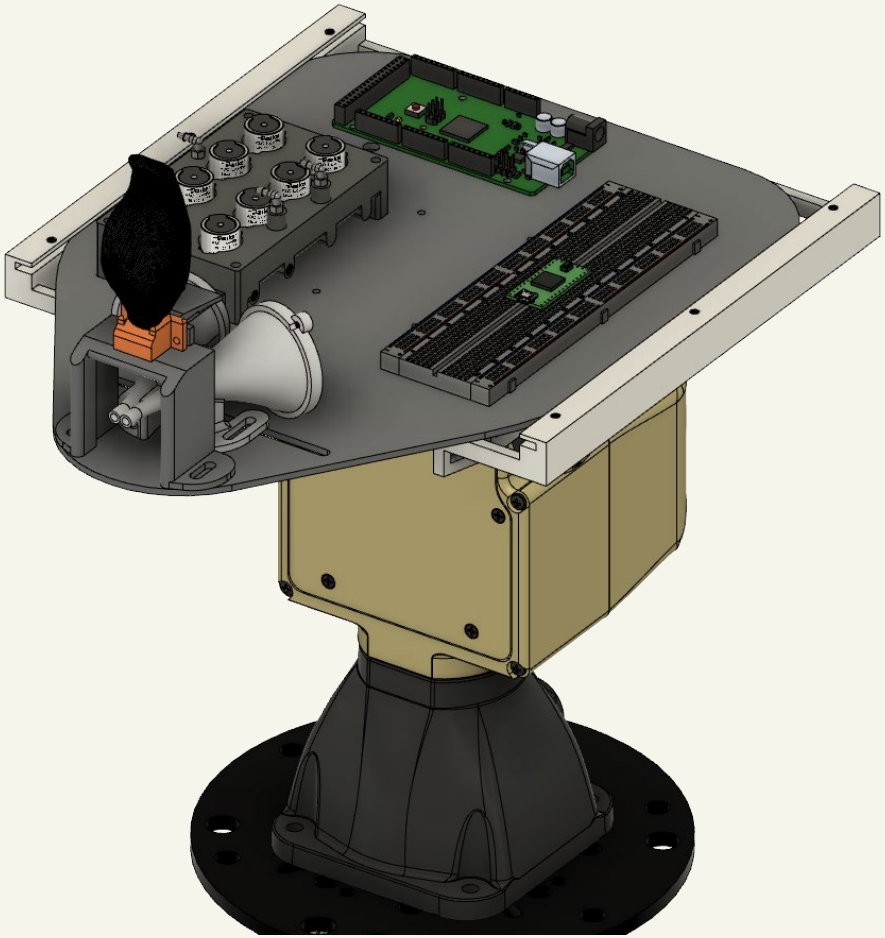
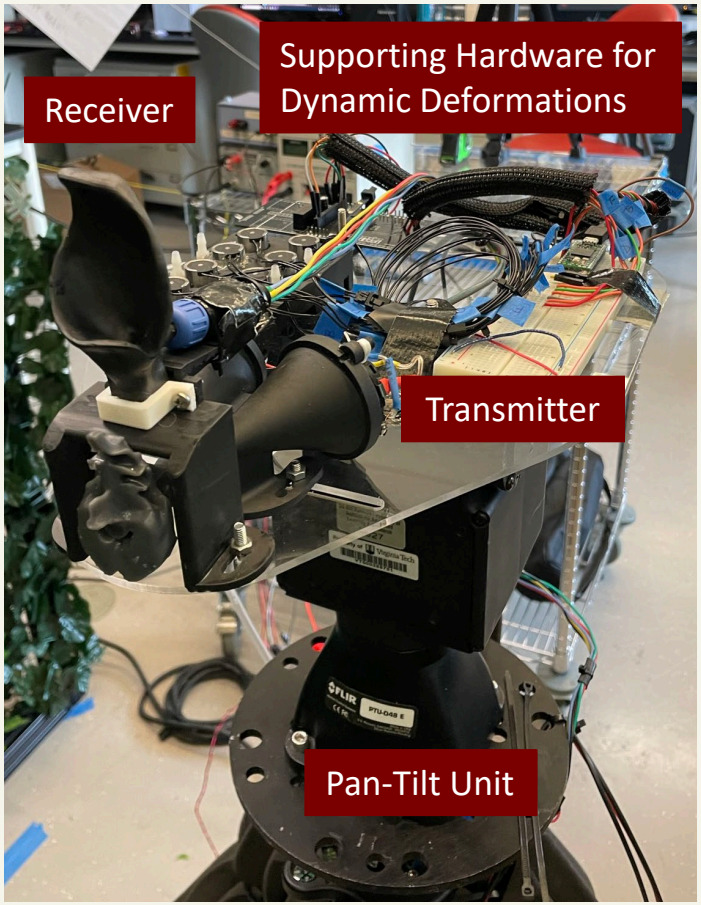
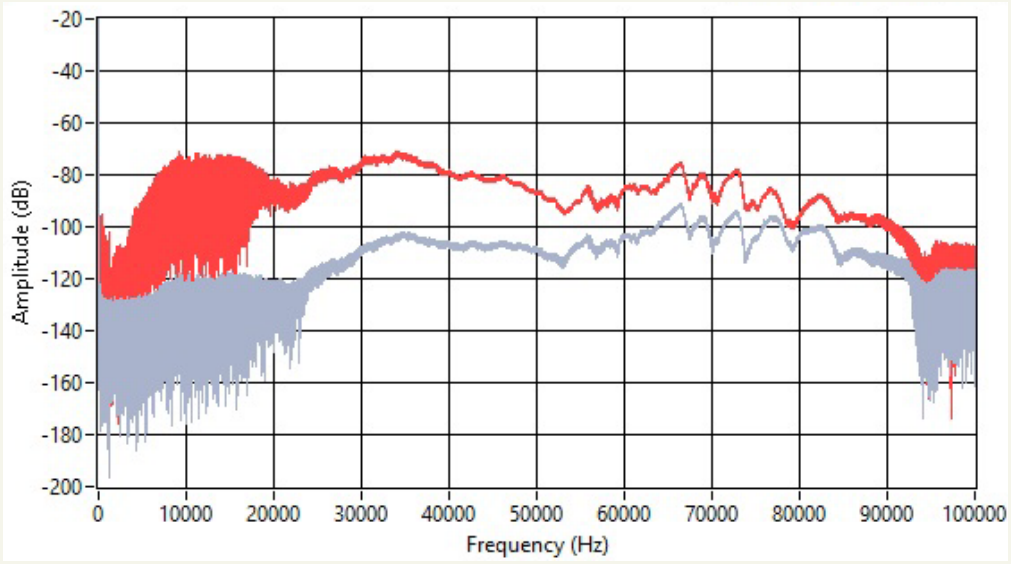
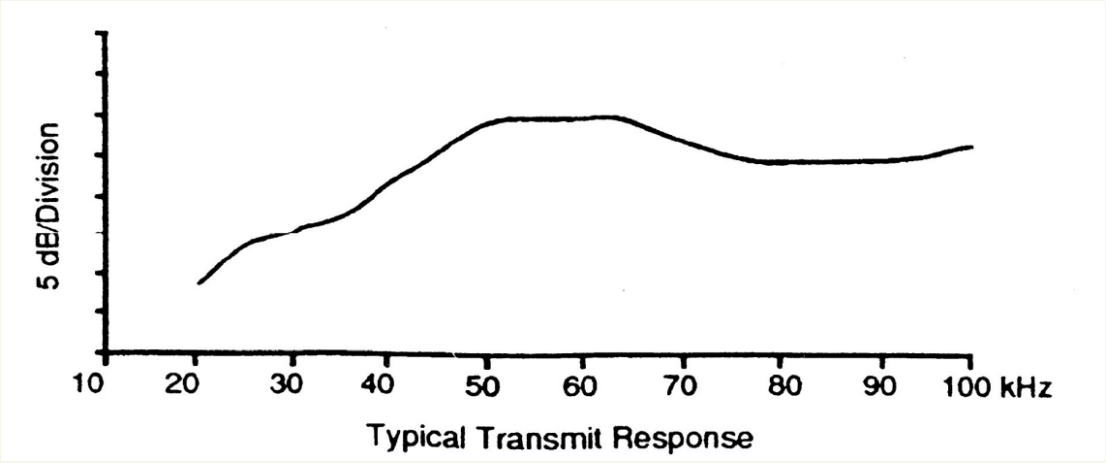




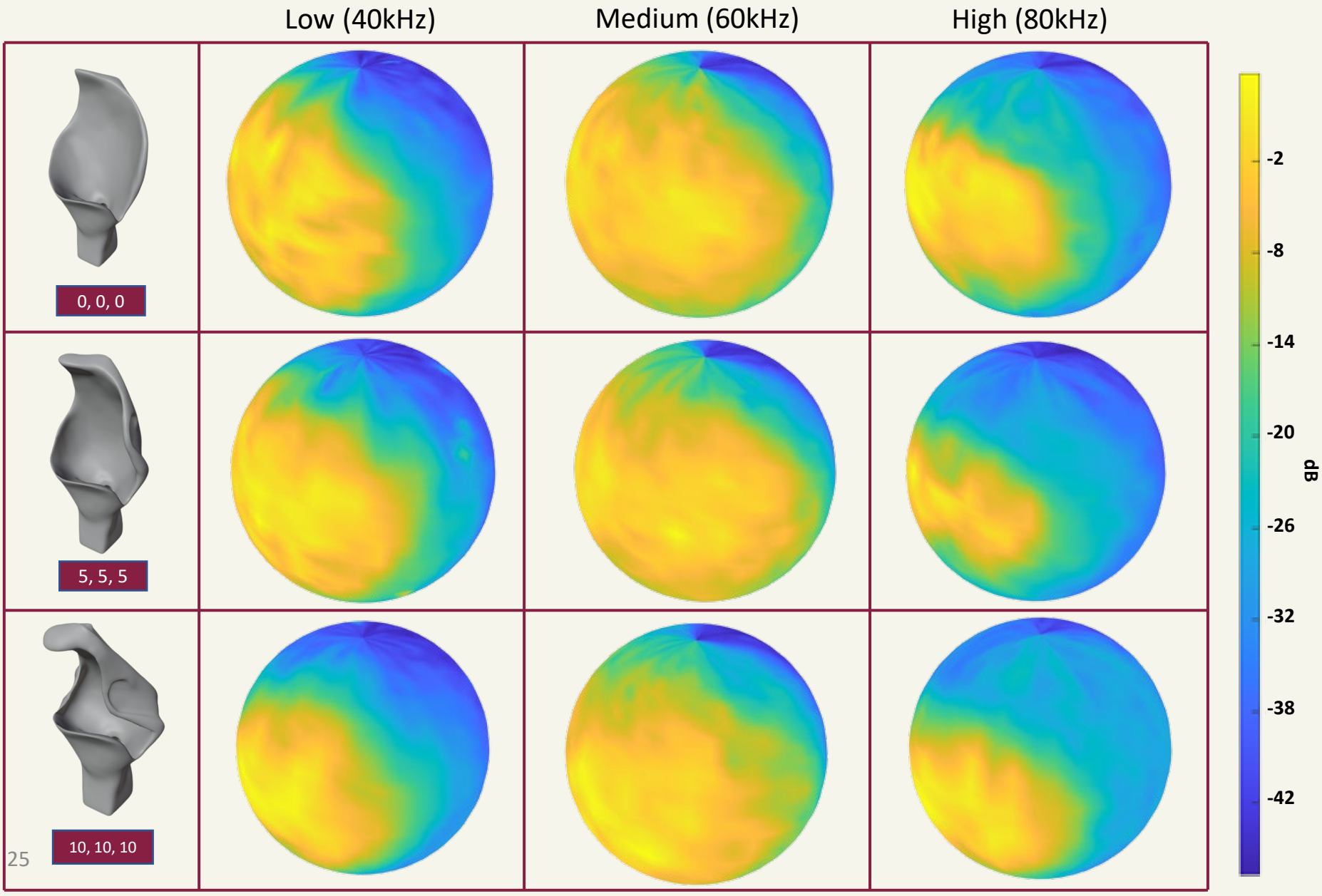
Static Characterization of Pinna: Beam Pattern Testing

Transmitter & Receiver Frequency Response

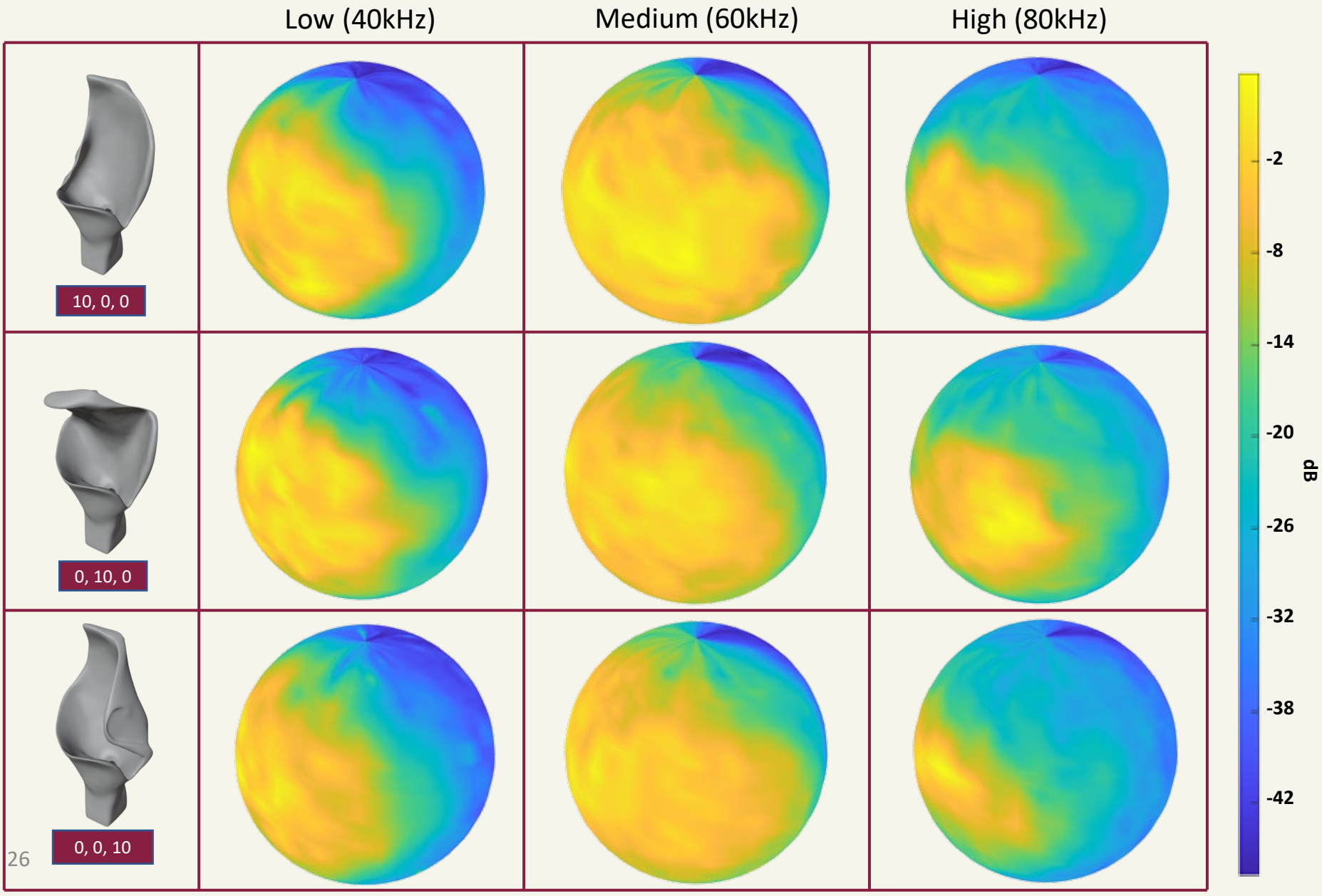




Beam Pattern Comparison — Set 1



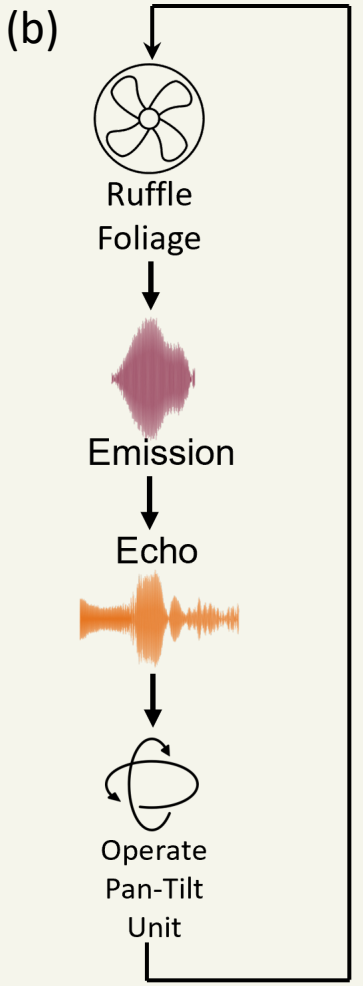
Beam Pattern Comparison — Set 2



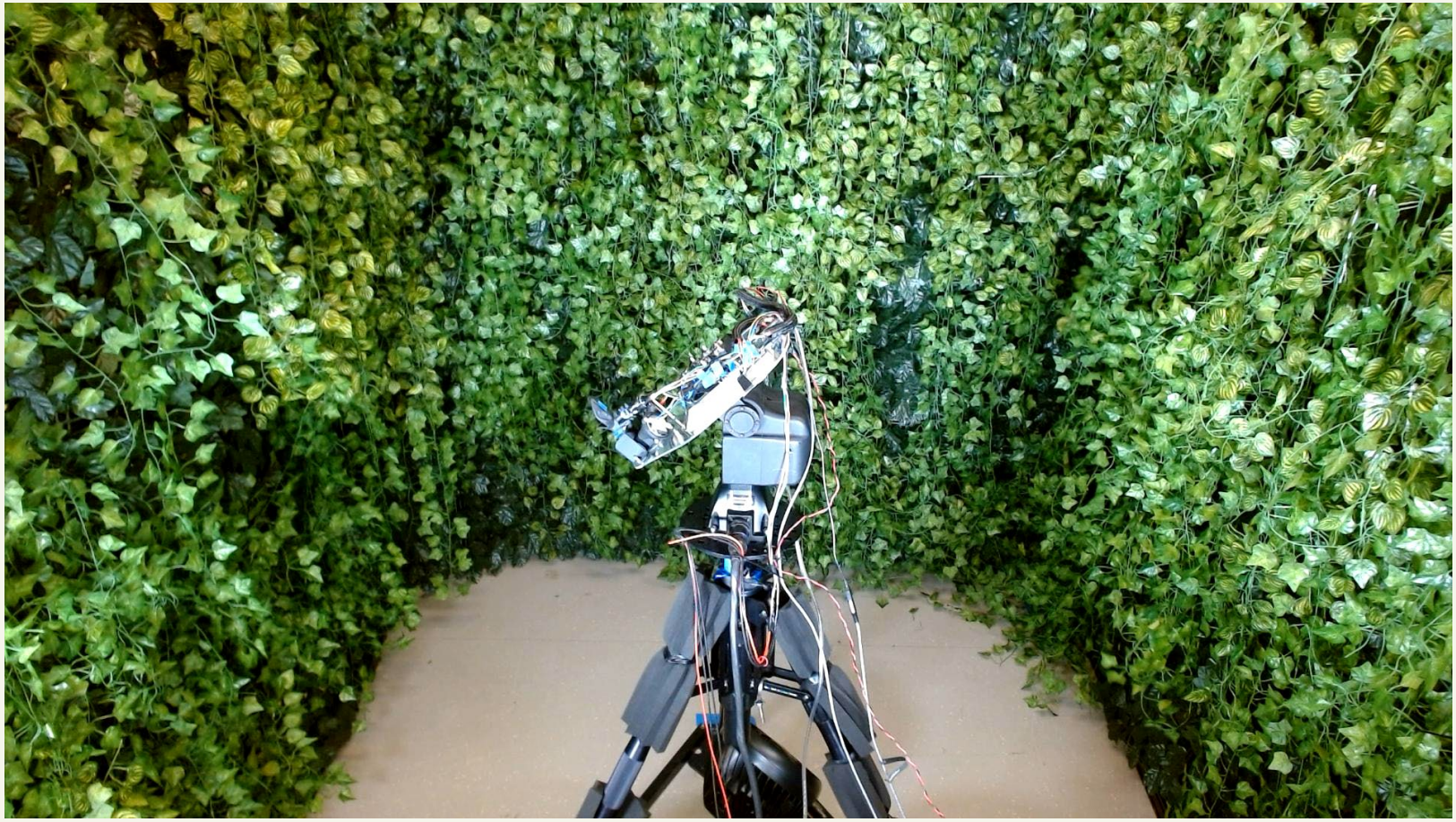
Experimental Lab Setup & Control Scheme for Echo Test

Experimental Setup for Echo Test

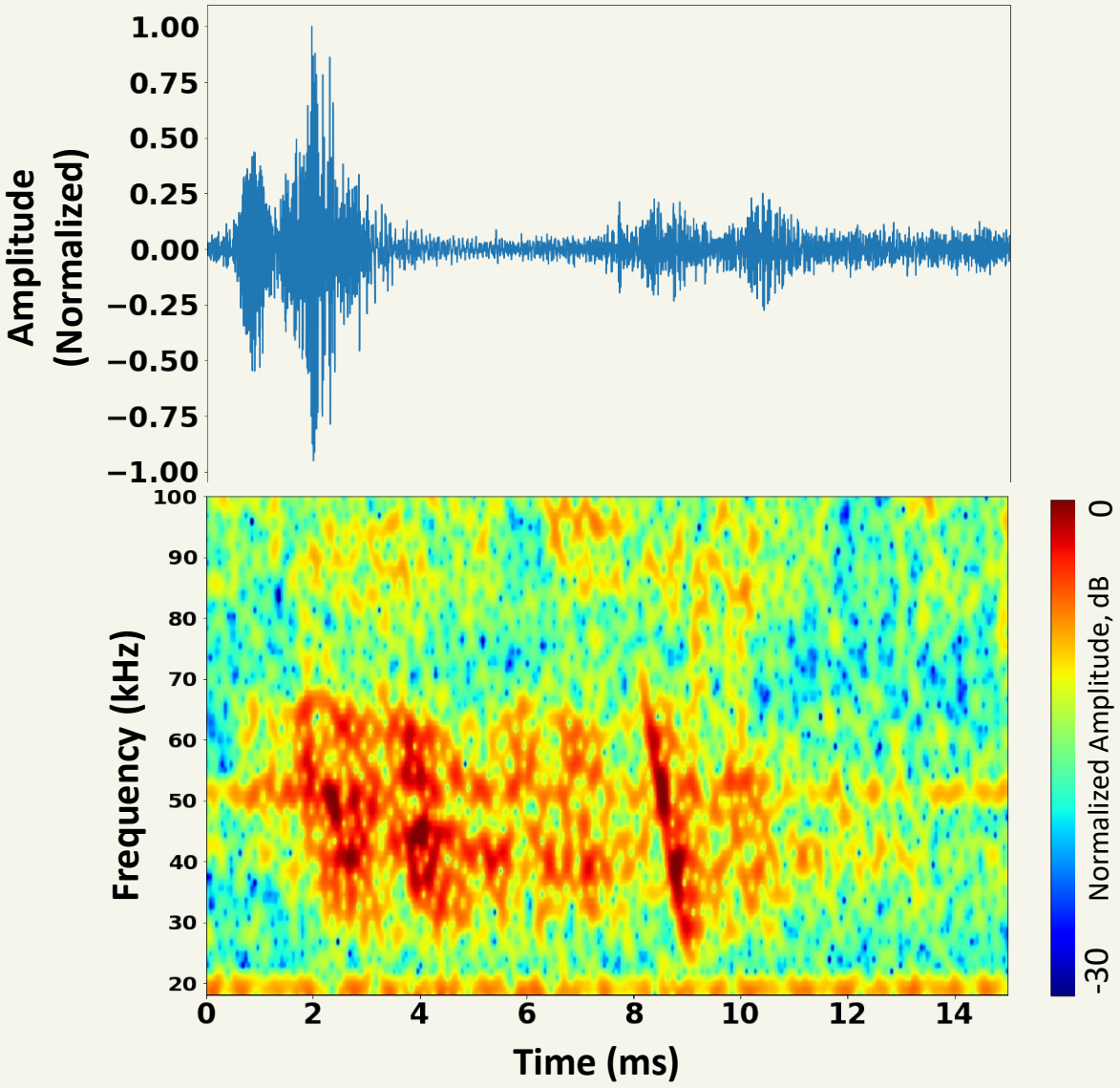
Control Scheme



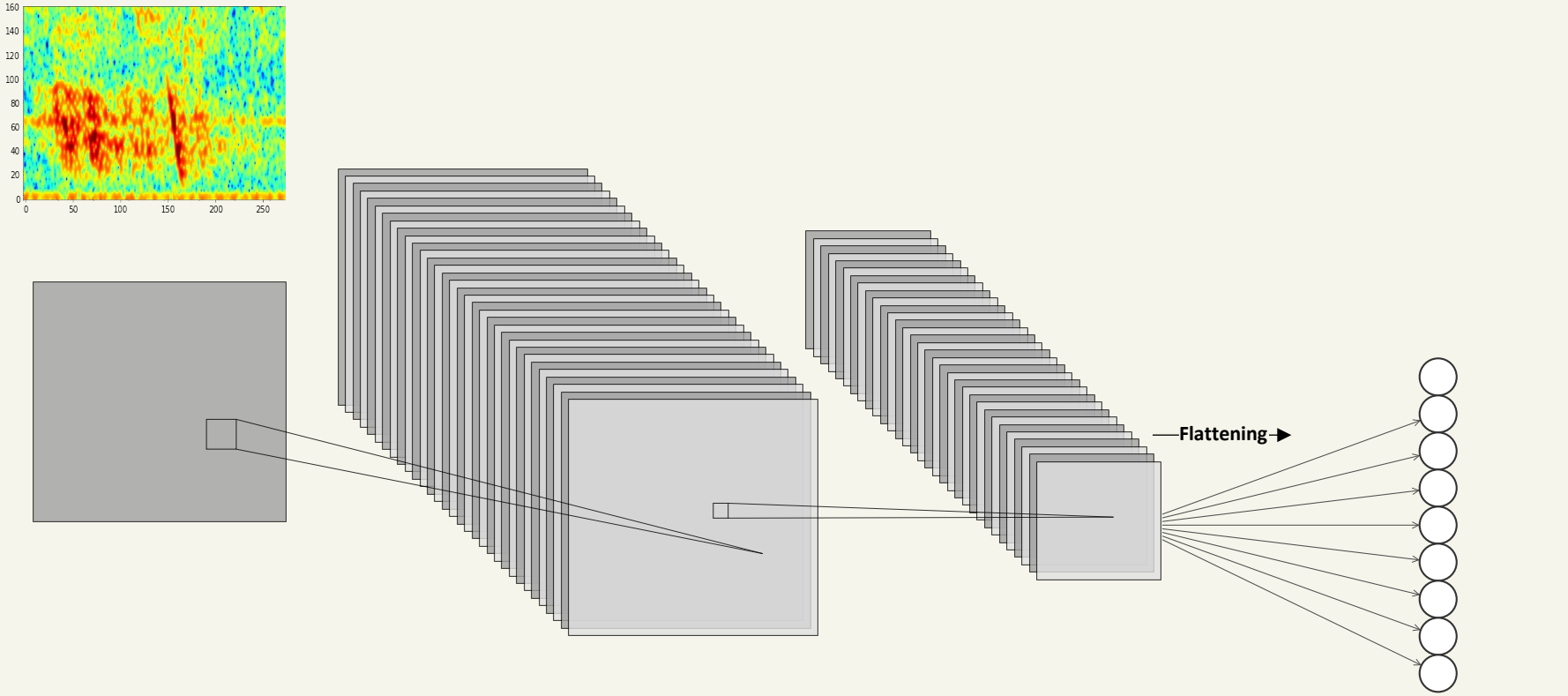
Time Lapse of an Experiment



Example of Echo Received From Foliage



Classification Network Architecture



Input

160x271

Convolutional Layer

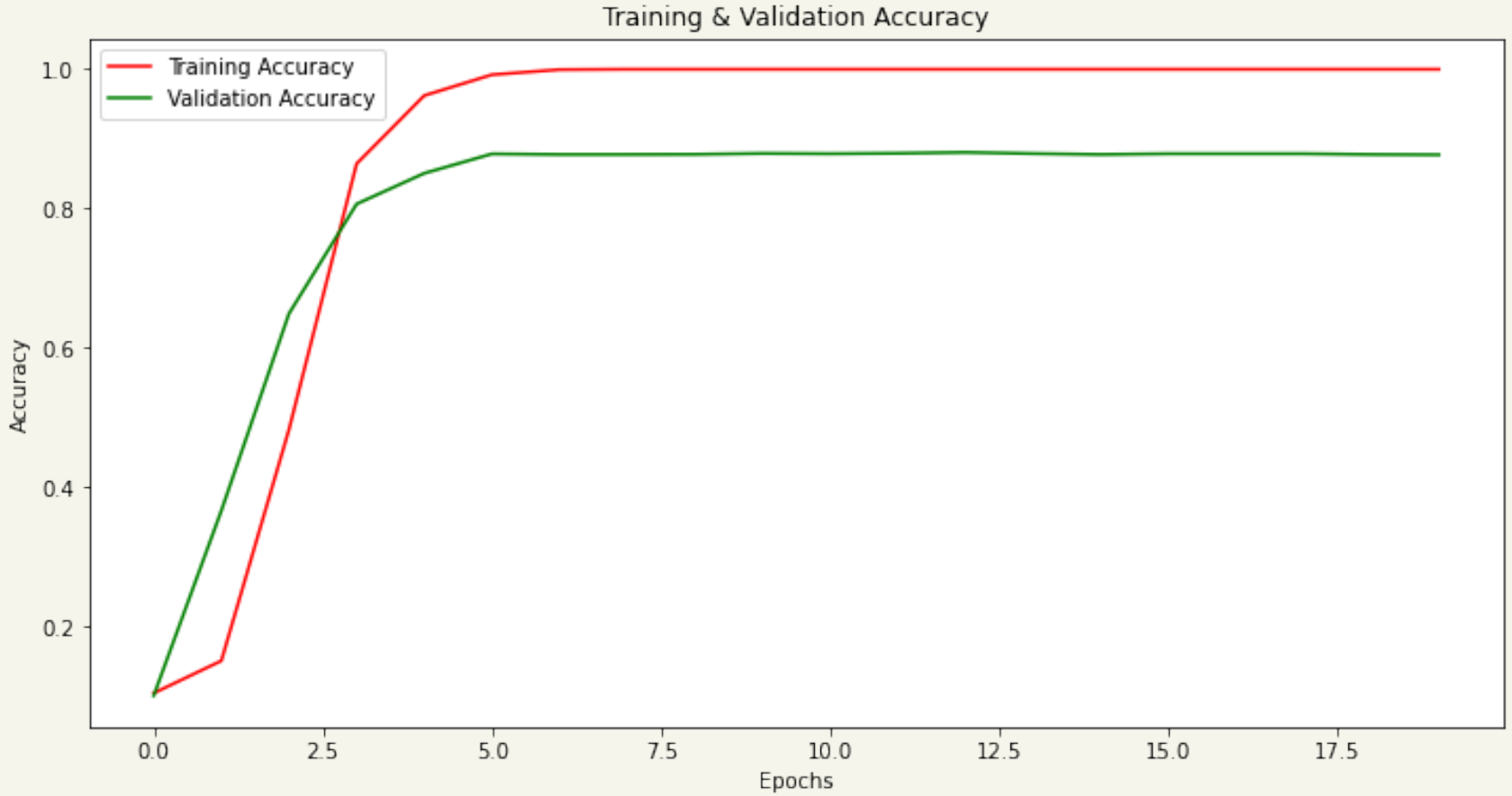
156x267x32

Max-Pooling Layer

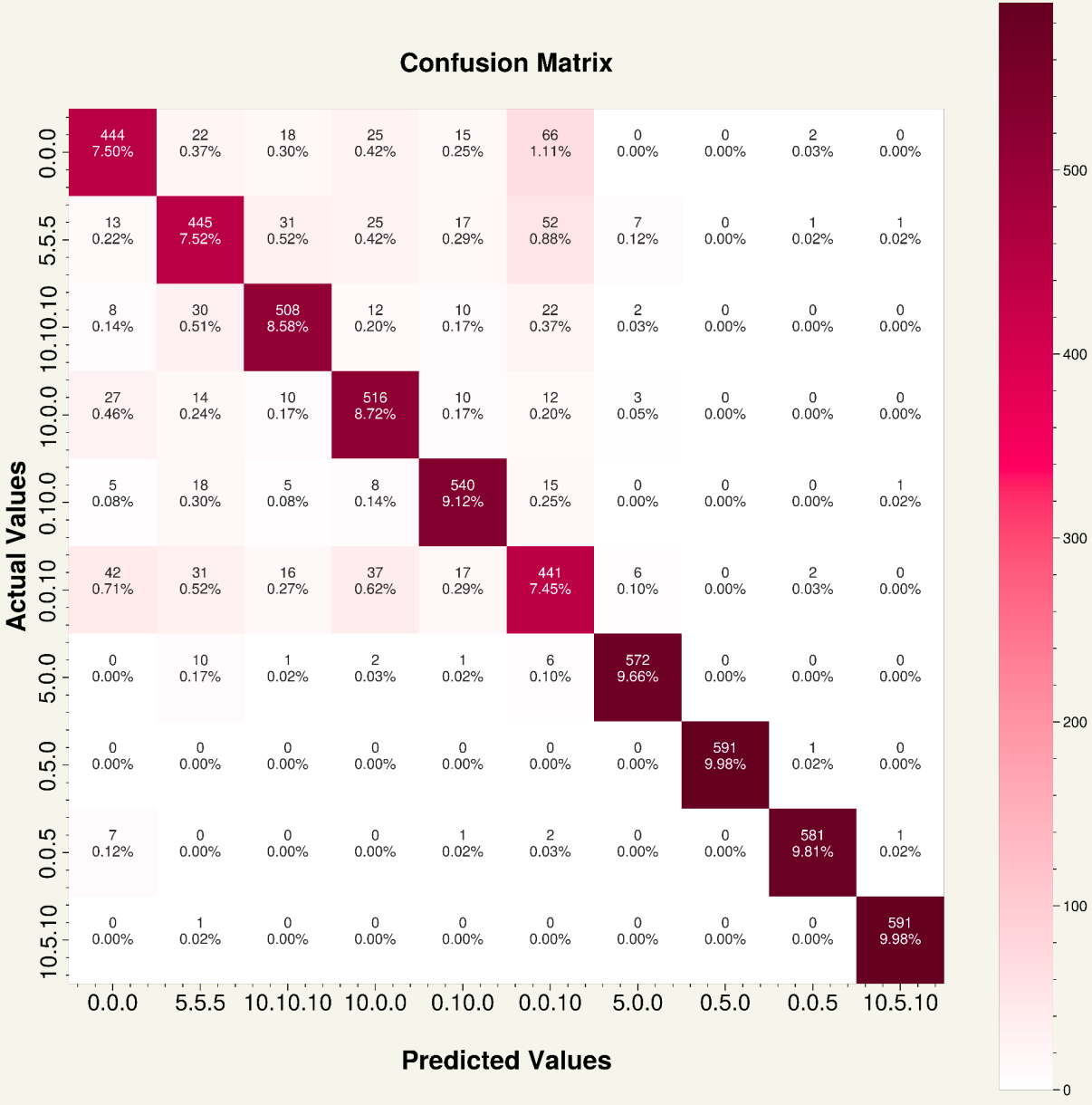
126x133x32

Output Layer

A Supervised Classification Problem

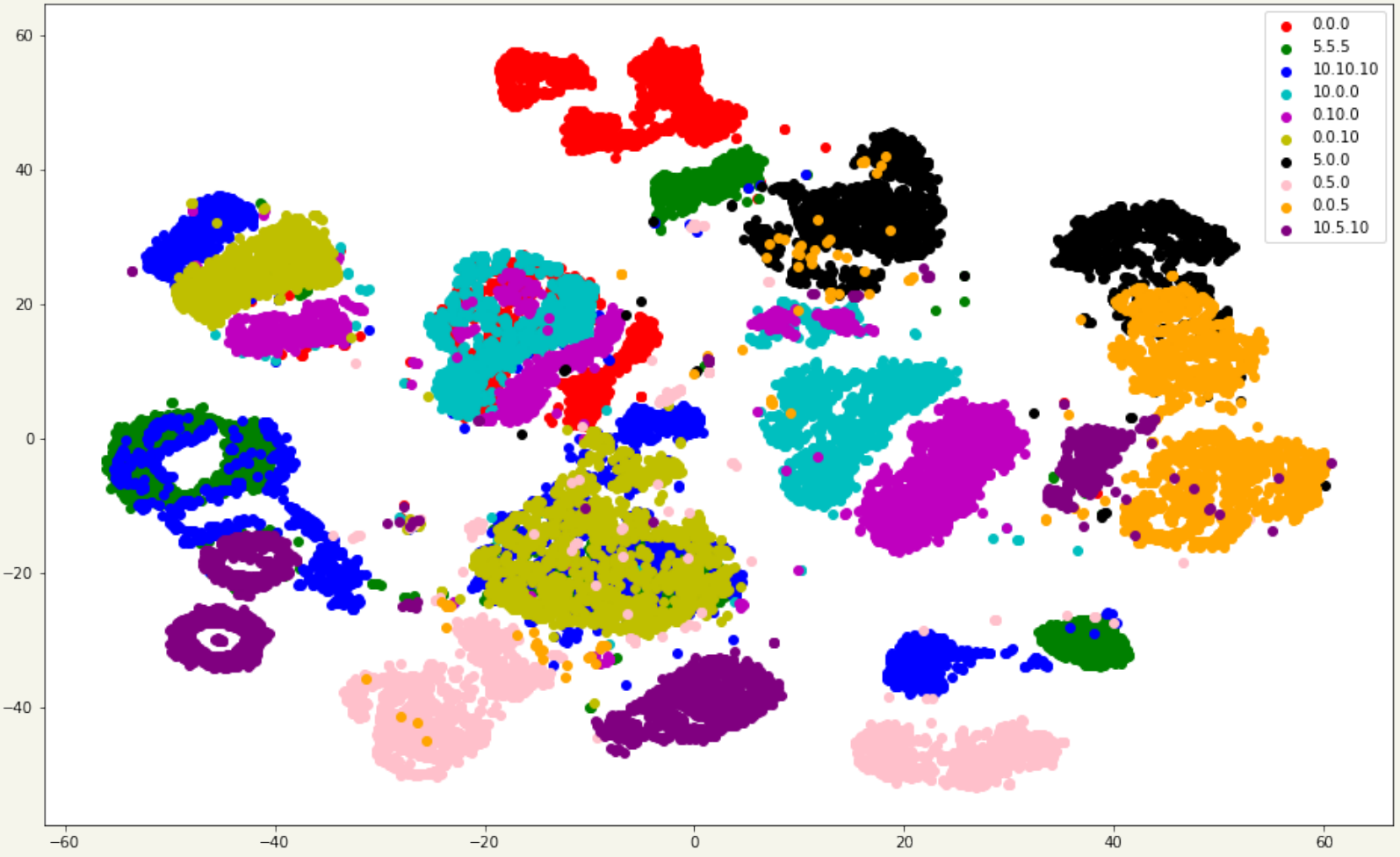


Confusion Matrix

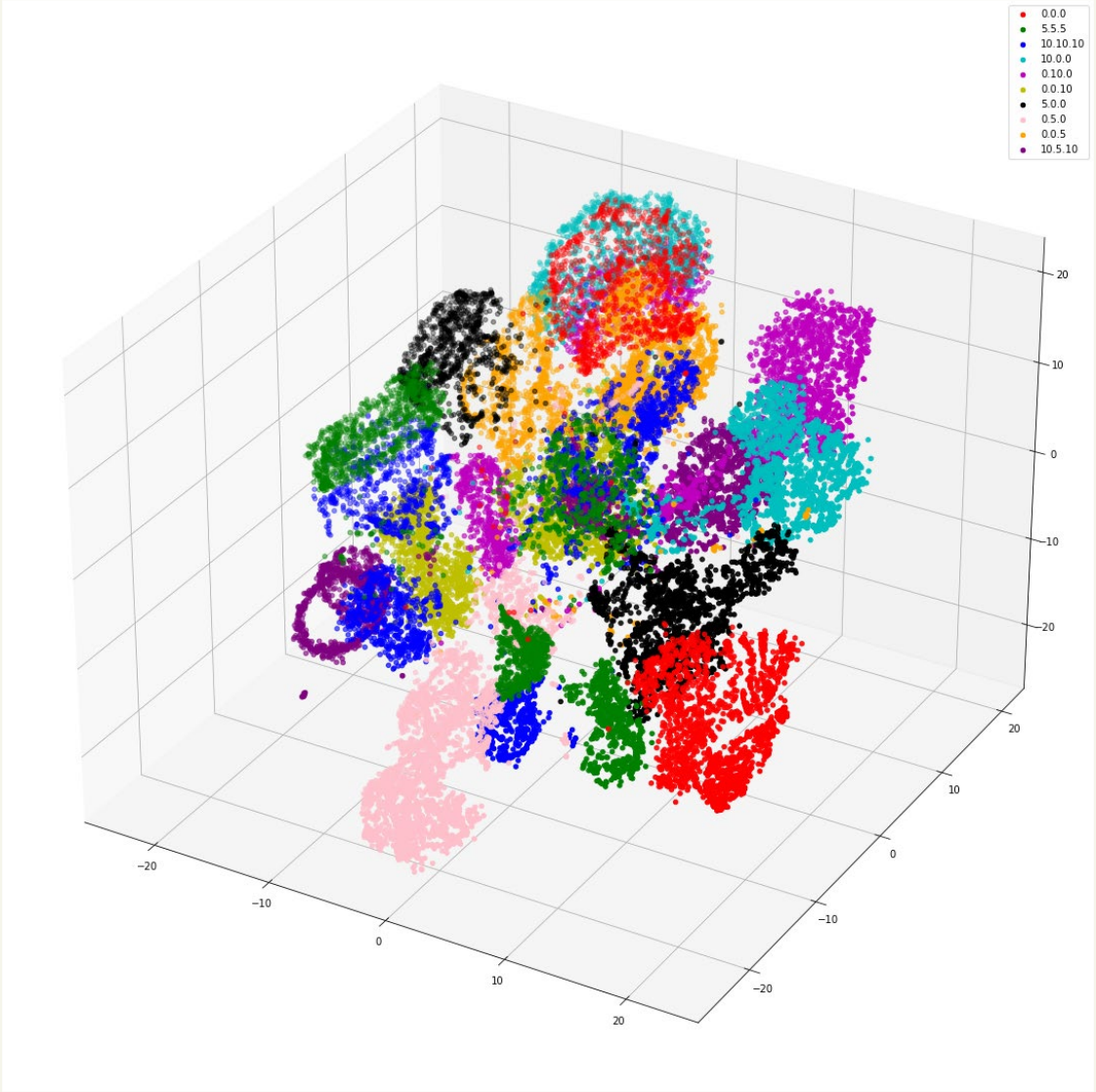


VIRGINIA TECH

Input Data Separability – t-SNE



Input Data Separability – t-SNE



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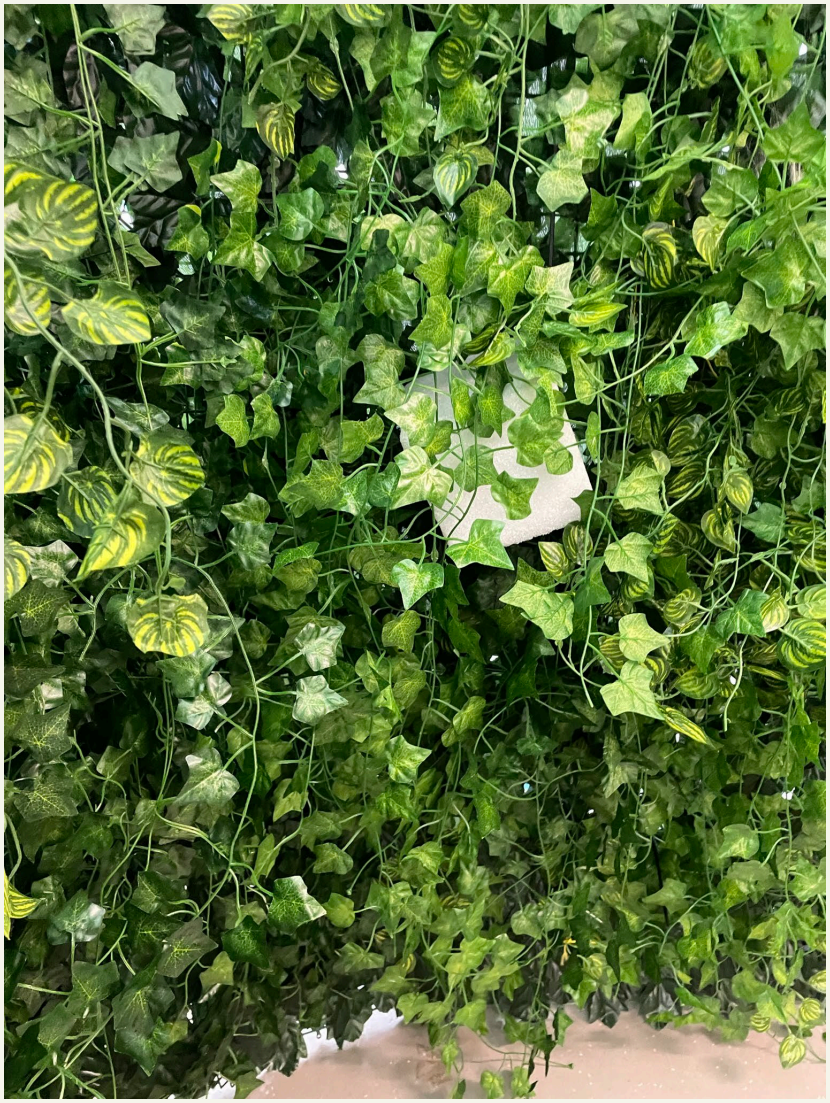
Target Detection & Localization



Applications in Agriculture

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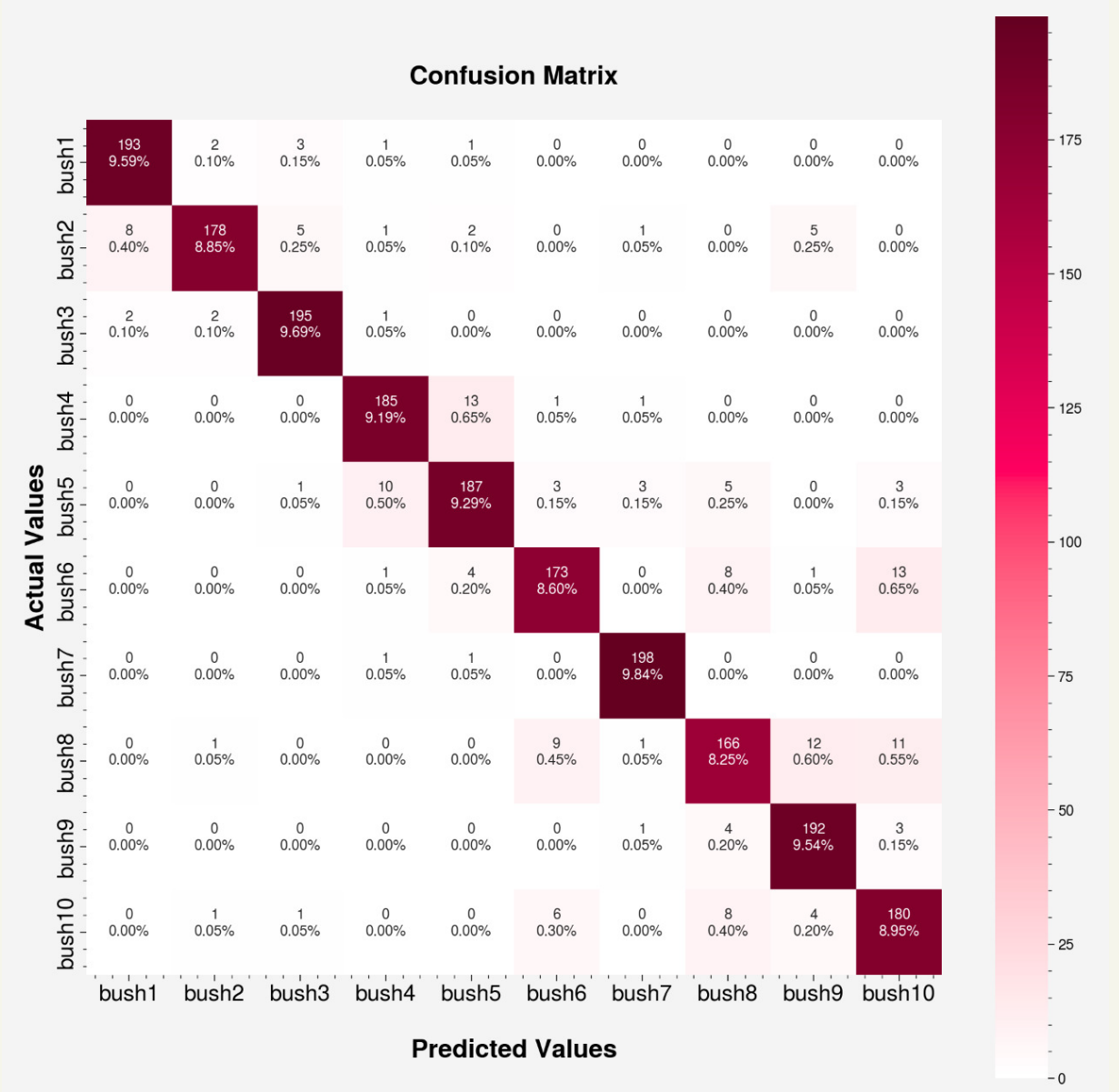
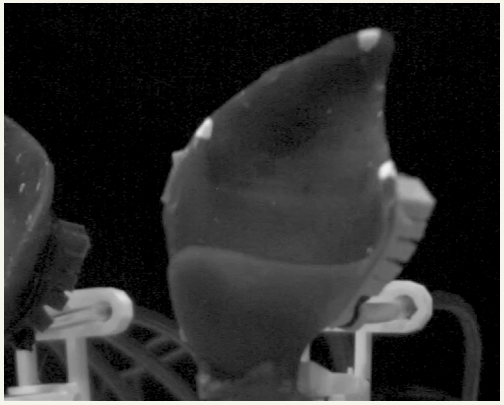
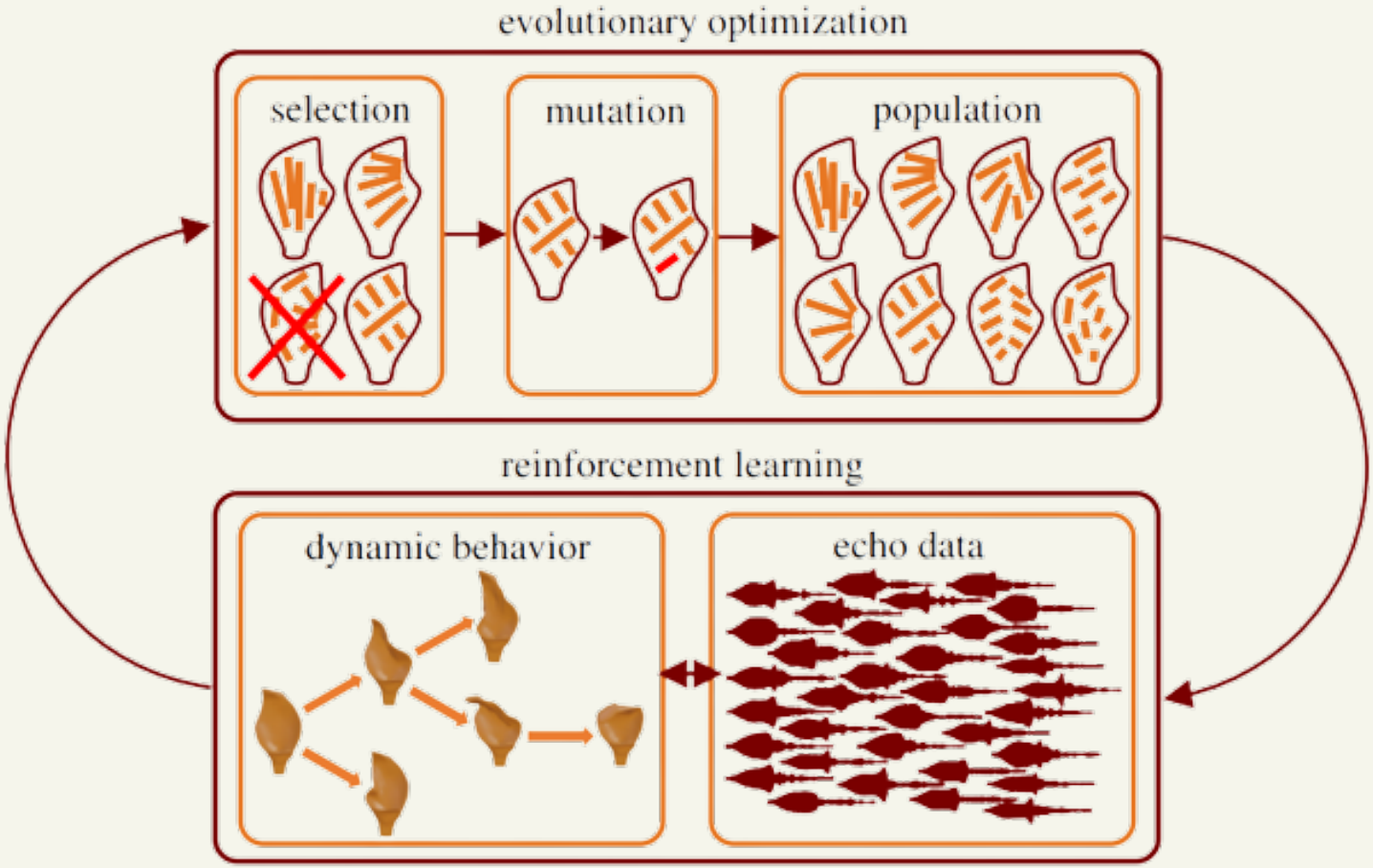


A Reinforcement Learning Problem



Overview of Deep Evolutionary RL Problem



Conference Presentations & Publications

Müller, R., Chakrabarti, S., **Eshera, I.**, Lagad, S. V., Wang, R., & Zhang, L. (2021). "Autonomy, soft-robotics, deep learning, and bat biosonar." *The Journal of the Acoustical Society of America (JASA)*, 150(4), A325-A325.

Lagad, S. V., **Eshera, I.**, Chakrabarti, S., & Müller, R. (2021). Development of a tension-controlled soft-robotic actuation system for a biomimetic bat robot *The Journal of the Acoustical Society of America (JASA),* 150(4), A324-A324.

Knoll, J., **Eshera, I.**, Shawky, M., DiMarino, C., Ghandi, R., ... & Buttay, C. (2021, June). Characterization of 4.5 kV Charge-Balanced SiC MOSFETs. In *2021 IEEE Applied Power Electronics Conference and Exposition (APEC)* (pp. 2217-2223). IEEE.

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