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Performance of Neural Networks in Source Localization using Artificial Lateral Line Sensor Configurations

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INTRODUCTION

Artificial lateral lines (ALLs) are used to detect the movement and locations of sources underwater, and are based on the neuromasts (fig. 1) located in the lateral line organ found in fish and amphibians. ALLs consists of a set of biaxial sensors (fig. 2).

RESEARCH QUESTIONS

Can the placement of artificial lateral line sensors be beneficial for improving the accuracy of source localization through the use of convolutional neural networks?

Are convolutional neural networks and extreme learning machines capable of predicting the locations of multiple sources in three-dimensional environments?

SOURCE LOCALIZATION PIPELINE

Data generation:
- source locations:
- sensor locations:
- teacher object: 3D matrix containing 1331 density probability points for source locations

Neural networks:
- convolutional neural network
- extreme learning machine

Sensor readings → 3D matrix

Source prediction process:
3D matrix → source predictions

k-means

METHODS

EXPERIMENT 1

A Cramér-Rao lower bound analysis was performed on a subset of sensor configurations (16 sensors, 1m³ basin) to estimate their likely performances and indicate the best and worst configurations.

EXPERIMENT 2

The best and worst configurations were used to generate simulated datasets to train and test extreme learning machines (ELMs) and convolutional neural networks (CNNs) on their location accuracy. Simulated datasets consisted of 2 sources in a 3D basin (1m³) and the sensor readings of 16 ALL sensors.

CONCLUSION

The optimal configuration improved performance for both sources, compared to other configurations. Therefore, the main research question can be answered positively in that using an optimal configuration can improve source localization performance using CNNs.

With regard to the secondary research question, both neural networks are capable of detecting two sources in a 3D environment, if sources are an equal distance removed from the ALL. If not, only the closest source to the array is accurately reconstructed.

The optimal configuration also improved ELM results for all source generation conditions; the use of an ELM leads to a higher performance of the worst estimated source, for the majority of conditions, compared to using a CNN.