ML Classification of Synthetic Acoustic Signatures

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Introduction

Active Acoustic Classification

Active acoustic classification involves using sound waves to detect and classify objects. This technique entails transmitting acoustic signals and analyzing their interactions with objects to determine certain characteristics.

Natural and Synthetic Returns

A key challenge in this research is to differentiate between natural acoustic returns and those modified by synthetic responses. Natural acoustic returns occur when an acoustic signal interacts with objects and is reflected back to the receiver. In this case, when the signal interacts with a target. In contrast, synthetic impulse responses introduce deliberate modifications to the signal, creating unique acoustic signatures.

Objectives

This project aims to study the detection of acoustic signatures by using machine learning techniques to distinguish between natural and synthetic acoustic returns. The central research question is: *"Can a machine learning model be used to distinguish subtle signal modifications?"*

- **Implement an air-like simulation in MATLAB** to facilitate waveform modification in a controlled environment
- **Generate natural and synthetic signal responses** to transmitted signals
- **Produce a proof-of-concept detection model** to prepare for experimental data

Methodology

Given the scarcity of experimental/real-world data, we opted to simulate our dataset using MATLAB. We decided to create a simulation that would generate an initial proof of concept detection model.

The signal that was studied in both setups was an up-sweep chirp signal.

Start Frequency	End Frequency	Sample Rate	Time
10000 Hz	20000 Hz	44100	1 second

Fig. 1: Chirp signal parameters

The simulation can be split into two setups: the Synthetic Response Model and the Reflector Model.

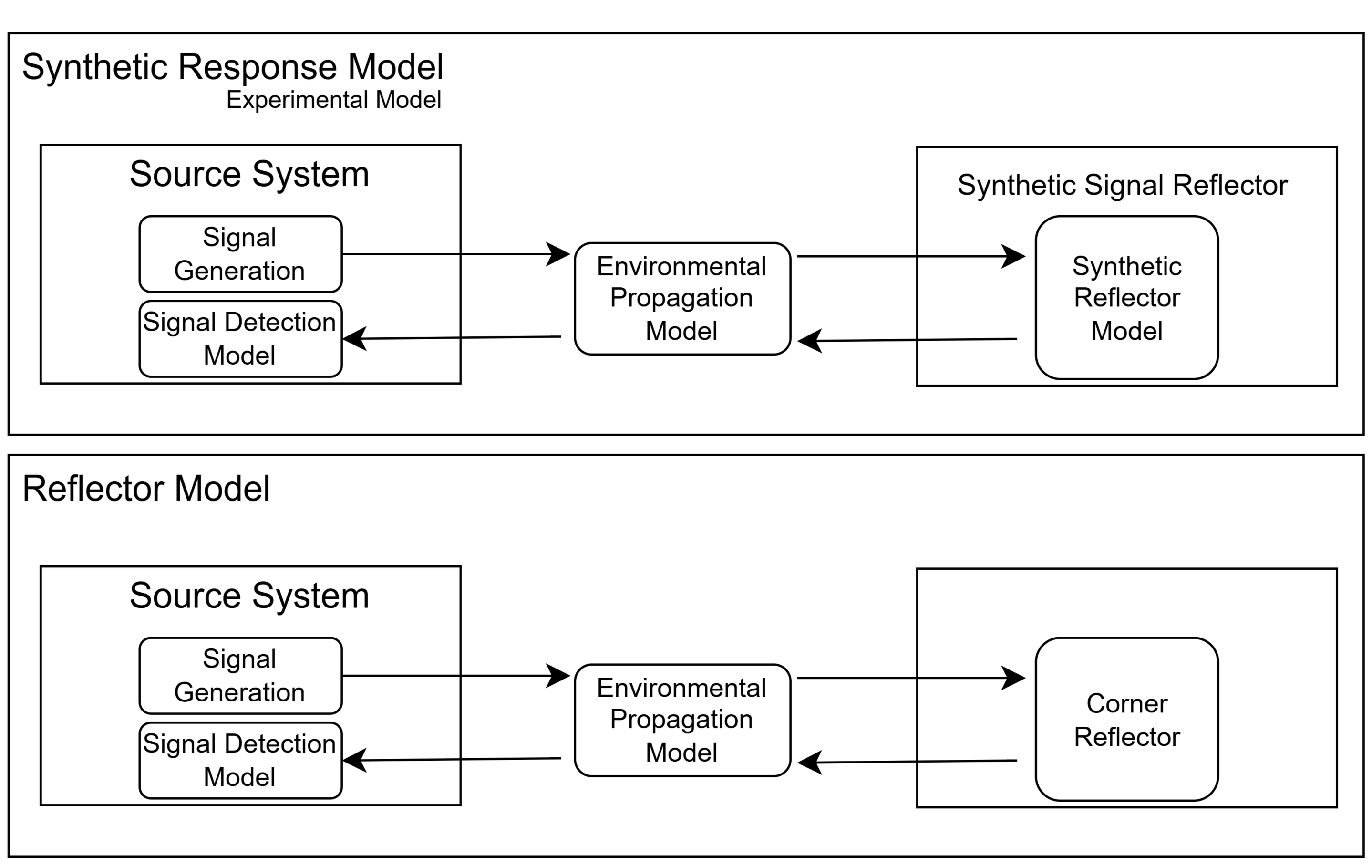

Fig. 2: Two models in classification simulation

The defining factor of each model:

- **Synthetic Response Model:** After the signal is propagated, the reflector adds a synthetic signature to its waveform. In this setup, this process is modelled using the convolution of a waveform with an impulse response (IR) that modifies the signal that is then propagated back to the source processing.
- **Reflector Model:** After the signal is propagated, the receiver in this set up computes the reflected signal from a target, aimed to behave like a corner reflector.

Results / Analysis

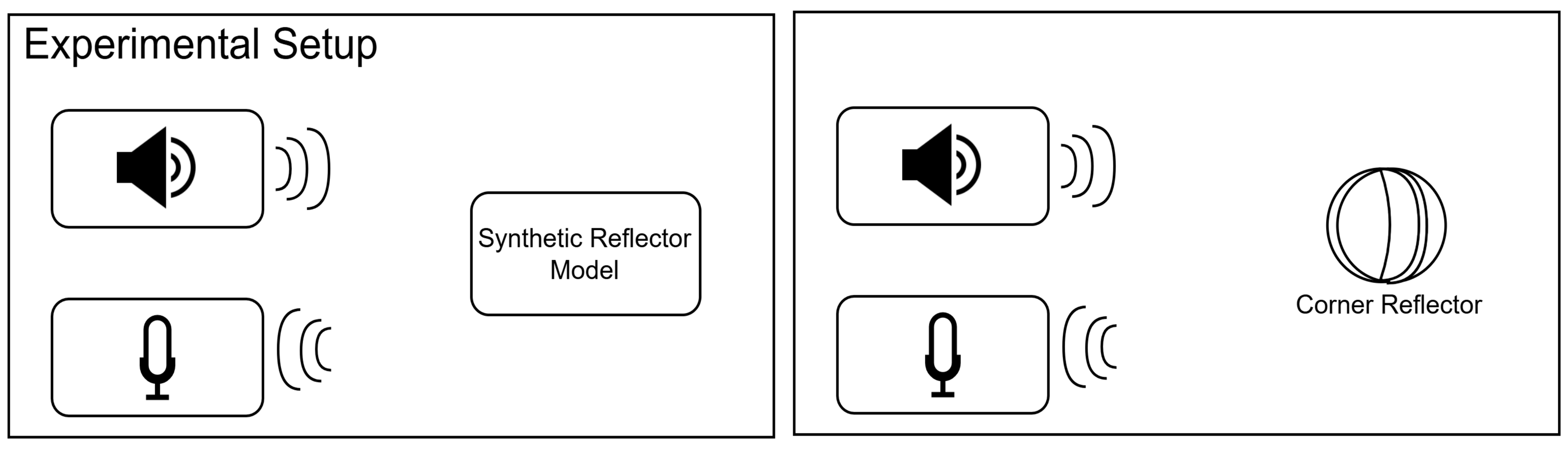

Fig. 3: Experimental setup of simulation

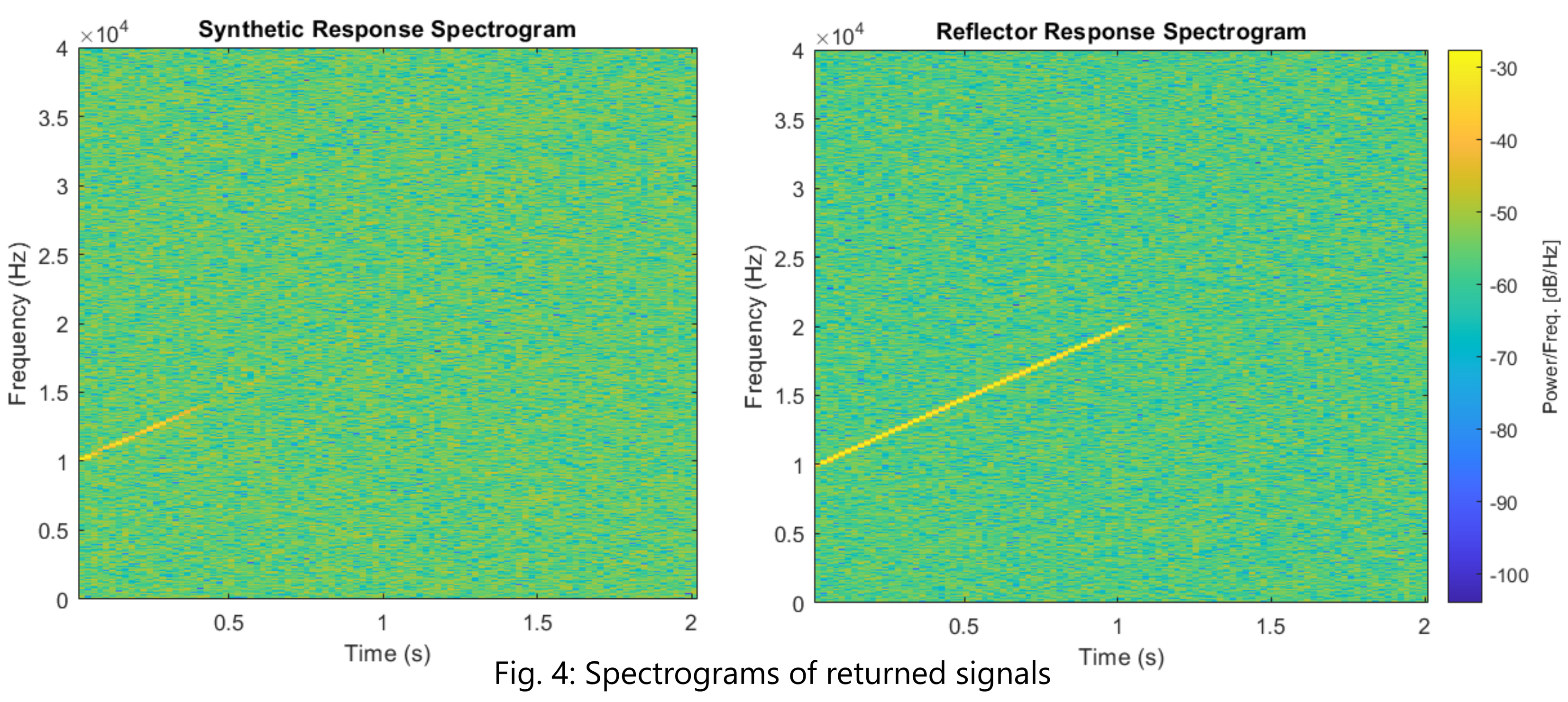

Fig. 4: Spectrograms of returned signals

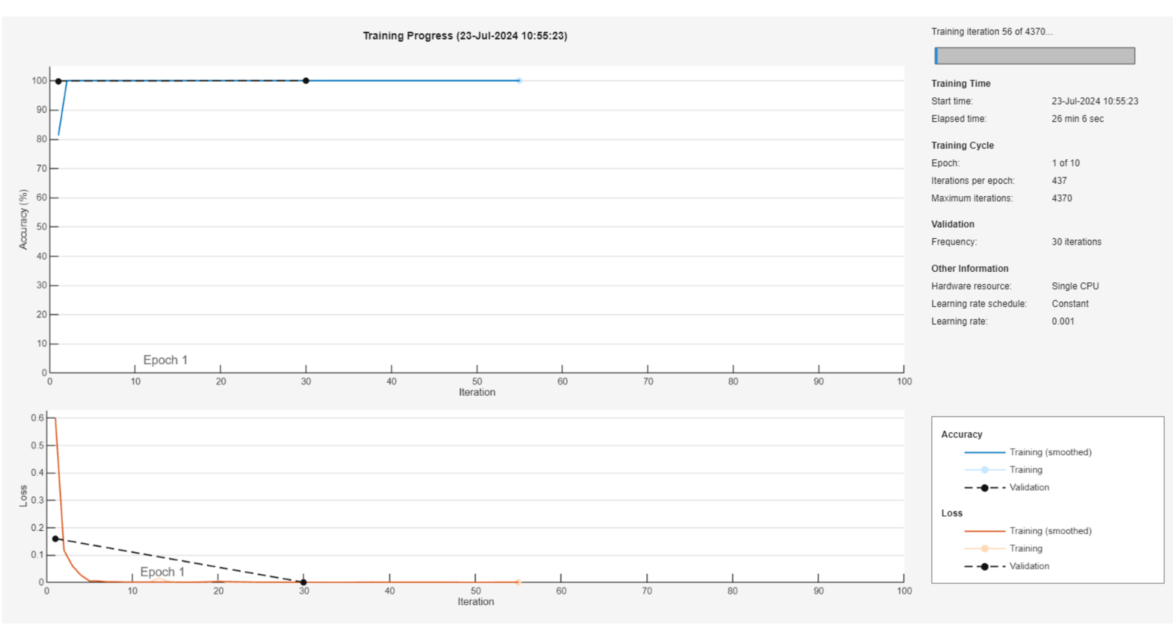

Fig. 5: Results of training a ResNet model

The model achieved very high accuracy during training, which was anticipated given the surrogate datasets used.

While the proof-of-concept results are promising, there are some limitations to consider:

- **Simulation Limits**: The use of simulated data may not capture the variation and complexity of the real-world environment.
- **Real-World Data Limits:** The signals and impulse responses were simulated. Further evaluation must be done with real-world data.

Future Objectives

Future research will focus on validating the model with real-world data following the initial proof-of-concept experiments. We plan to incorporate in-air experimental data to enhance our understanding of the model's capabilities, allowing a crucial bridge from simulated conditions to real world conditions.

The next steps would involve assessing the model's performance with a broader range of targets and environmental conditions. This includes evaluating its ability to handle diverse acoustic environments and varying signal types, which is crucial in evaluating its reliability and generalizability.

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