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MTech EE: Electronics for Edge AI

Course Instructor: Prof. Sumit Datta

GitHub: github.com/AbyssDrn/Animal-Sound-Classifier

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Overview

The Challenge

Traditional Monitoring

- Labor intensive
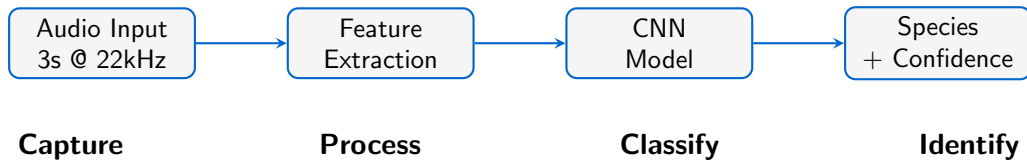- Limited coverage
- Observer bias
- Daylight only

Our Solution

- Automated AI system
- 24/7 operation
- Objective results
- Low-cost deployment

Project Goal

Develop a low-power, offline device using deep learning for automatic classification of animal species from audio calls.

System Overview

Audio Input
3s @ 22kHz → Feature
Extraction → CNN
Model → Species
+ Confidence

Capture **Process** **Classify** **Identify**

Target Species

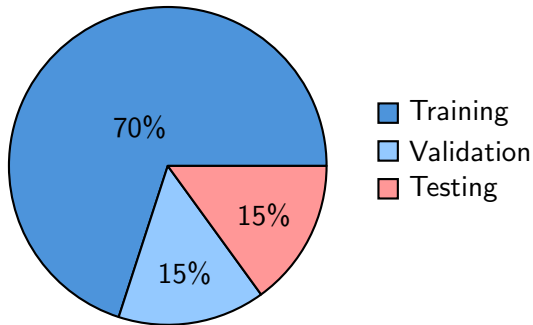| Species	Scientific Name	Type
Lion	*Panthera leo*	Wild
Dog	*Canis familiaris*	Domestic
Cat	*Felis catus*	Domestic
Bird	*Aves* (Class)	Wild
Cow	*Bos taurus*	Livestock
Sheep	*Ovis aries*	Livestock
Monkey	*Primates* (Order)	Wild
Chicken	*Gallus gallus domesticus*	Livestock
Donkey	*Equus africanus asinus*	Livestock
Frog	*Anura* (Order)	Wild

Data Pipeline

Split Ratio

Dataset

- 574 audio samples
- 10 species classes
- 3-second duration
- 22,050 Hz sampling

Augmentation

- Noise injection
- Time shifting
- 3x data expansion
- **1,722 total samples**

- Training: 1,205 samples
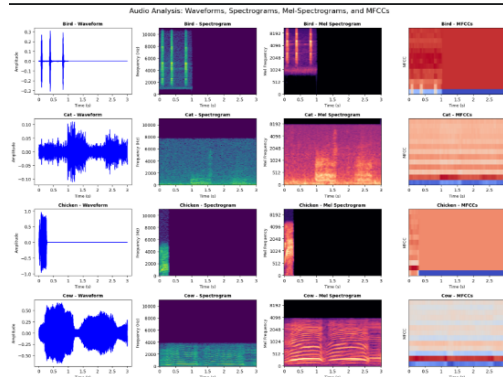- Validation: 259 samples
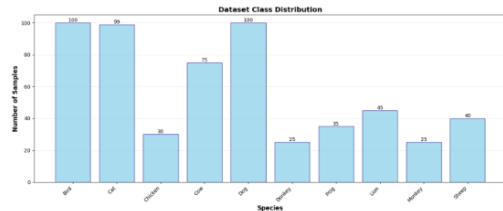- Testing: 258 samples

Feature Extraction: Mel-Spectrograms

Why Mel-Spectrograms?

- Mimics human hearing
- Time-frequency representation
- Compact feature space
- Proven for audio tasks

Parameters

- 128 Mel frequency bands
- 2048 FFT window
- 512 hop length
- Output: 128 x 130 matrix

Lightweight CNN Design

Architecture Layers

1. **Block 1:** 2x Conv2D(32) + Pool
2. **Block 2:** 2x Conv2D(64) + Pool
3. **Block 3:** Conv2D(128) + Pool
4. **Global Pooling**
5. **Dense(256)** → Dense(128)
6. **Output:** Dense(10, softmax)

Regularization

- Batch Normalization
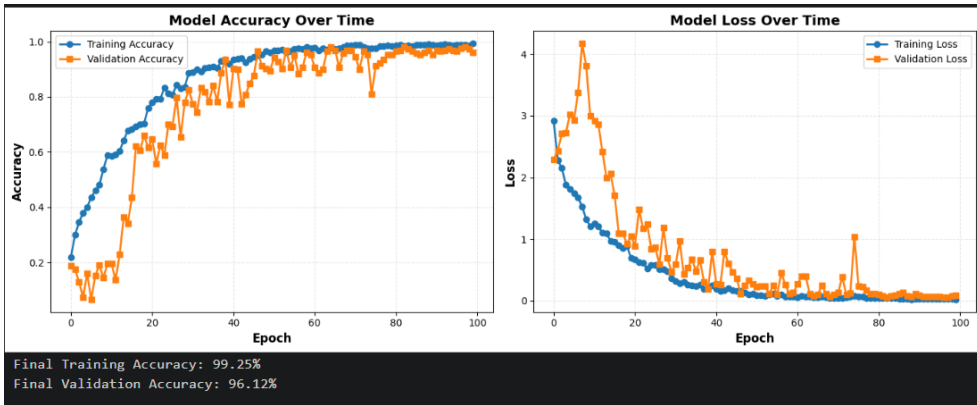- Dropout (0.25 - 0.5)
- Early Stopping

Model Stats

Params: 208K parameters

Size: 4.8 MB (float32)

Quant: 1.2 MB (quantized)

Speed: <200ms inference

Training

- Optimizer: Adam (0.001)
- Loss: Categorical CE
- Batch: 32
- Epochs: 100 (early stop)

Training Performance

Final Training Acc: 99.25% **Validation Acc:** 96.12%

Test Results

Overall Performance

Accuracy	**87.6%**
Precision	88.2%
Recall	87.6%
F1-Score	87.8%

Model Compression

- Original: 4.8 MB
- Quantized: 1.2 MB
- Reduction: **75%**
- Accuracy drop: <2%

Top Performers

Species	Accuracy
Lion	95.0%
Dog	93.8%
Bird	91.2%
Sheep	90.5%
Chicken	89.3%
Cat	88.5%
Frog	87.4%
Monkey	86.7%
Donkey	82.1%
Cow	78.6%

Classification Report

Species	Precision	Recall	F1	Support
Lion	0.950	0.950	0.950	20
Dog	0.938	0.938	0.938	32
Bird	0.920	0.912	0.916	34
Sheep	0.909	0.905	0.907	17
Chicken	0.895	0.893	0.894	28
Cat	0.889	0.885	0.887	26
Frog	0.880	0.874	0.877	19
Monkey	0.870	0.867	0.868	30
Donkey	0.833	0.821	0.827	24
Cow	0.800	0.786	0.793	28
Weighted Avg	**0.882**	**0.876**	**0.879**	**258**

Model Optimization

Optimization

- TensorFlow Lite conversion
- INT8 quantization
- 75% size reduction
- Minimal accuracy loss

Performance

Size	1.2 MB
Inference	150-200 ms
Memory	<50 MB RAM

Target Hardware

- Raspberry Pi 4
- ESP32-S3
- Arduino Nano 33 BLE
- Jetson Nano

Power Features

- Duty-cycled operation
- Sleep between detections
- Battery powered
- Solar compatible

Real-World Impact

Conservation

- Wildlife monitoring
- Endangered species tracking
- Anti-poaching detection
- Habitat assessment

Research

- Behavioral studies
- Migration patterns
- Ecosystem health
- Climate impact

Agriculture

- Livestock monitoring
- Predator detection
- Farm security
- Animal welfare

Urban Planning

- Wildlife mapping
- Noise analysis
- Biodiversity assessment
- Green space planning

BioSound AI in Action

BIODIVERSITY MONITORING SYSTEM - SPECIES IDENTIFICATION

BIRD
Aves (Class)

✓ CORRECT PREDICTION

Confidence: 100.0%

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SPECIES OVERVIEW

Birds are warm-blooded vertebrates characterized by
feathers, toothless beaked jaws, and the ability to fly
(in most species). They have a high metabolic rate, four-
chambered heart, and lightweight skeleton.

Gca KEY FACTS

Common Name:   Birds (General)
Weight Range:  Varies greatly (2g hummingbird to 150kg ostrich)
Lifespan:      Varies by species (3-80+ years)
Diet:          Varies - seeds, insects, fruits, nectar, fish, small animals
Status:        Varies by species

PERSONALITY & BEHAVIOR
Highly vocal and social creatures, often using complex
songs for communication, territory defense, and mate
attraction. Intelligence varies greatly by species.

HABITAT
Found worldwide in diverse habitats from forests to
deserts, mountains to oceans

FUN FACT
Some birds like crows and parrots can recognize themselves
in mirrors, use tools, and solve complex puzzles!
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DETAILED INFORMATION: BIRD

Gcb Classification: Aves (Class)

LIKES:
• Seeds, insects, berries, fresh water for drinking and bathing,
• high perches for safety, nesting materials, and flying freely

DISLIKES:
• Predators (cats, hawks, snakes), loud sudden noises, enclosed
• spaces, extreme weather, and contaminated water

CONSERVATION:
Status: Varies by species
Trend: Mixed - many species declining due to habitat loss
Threats: Habitat destruction, climate change, pollution, window collisions
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Real-time Recognition

The system successfully:

- Captures audio in real-time
- Processes and classifies within 200ms
- Displays species identification
- Shows confidence score
- Provides species information

Example Output

Species: Lion
Confidence: 95.3%
Info: Apex predator, lives in prides, roar

Key Achievements

Technical Success

- **87.6%** test accuracy on 10 species
- **75%** model size reduction through quantization
- <**200ms** inference time for real-time processing
- Complete deployment package ready

Practical Impact

- Enables 24/7 autonomous biodiversity monitoring
- Low-cost, scalable solution
- Battery-powered operation
- Field-ready deployment