WRITEUP ON AI_MODEL TRAINING

Used the following python script to create and train data for the mode

```
 GNU nano 8.6                                  msitushield_model.py
import numpy as np
import tensorflow as tf
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Conv2D, MaxPooling2D, Flatten, BatchNormalization, I
from tensorflow.keras.utils import to_categorical
from sklearn.model_selection import train_test_split
import scipy.signal # Use scipy.signal directly

# —— 1. Configuration & Hyperparameters ——

SAMPLE_RATE = 16000  # Hz, typical for audio processing
DURATION = 2.0       # seconds per audio clip
N_SAMPLES = int(SAMPLE_RATE * DURATION)
N_MFCC = 13          # Number of MFCC features to extract

# Data generation parameters
N_SAMPLES_PER_CLASS = 500 # Number of synthetic samples to generate for each class

# Model parameters
# We will define the input shape dynamically after feature extraction
NUM_CLASSES = 3 # chainsaw, truck_engine, forest_noise
EPOCHS = 50
BATCH_SIZE = 32

# —— 2. Synthetic Data Generation ——

def generate_sine_wave(frequency, duration, sample_rate, amplitude=0.5):
    """Generates a pure sine wave."""
    t = np.linspace(0, duration, int(sample_rate * duration), endpoint=False)
    return amplitude * np.sin(2 * np.pi * frequency * t)

def generate_white_noise(duration, sample_rate, amplitude=0.1):
    """Generates white noise."""
    return amplitude * np.random.randn(int(sample_rate * duration))
```

```
Session  Actions  Edit  View  Help

(venv)-(mtalaki㉿Incognito)-[~/AI_MODEL/venv/bin]
$ pip install tensorflow numpy scipy scikit-learn matplotlib
Collecting tensorflow
  Downloading tensorflow-2.20.0-cp313-cp313-manylinux_2_17_x86_64.manylinux2
Collecting numpy
  Downloading numpy-2.3.5-cp313-cp313-manylinux_2_27_x86_64.manylinux_2_28_x
Collecting scipy
  Using cached scipy-1.16.3-cp313-cp313-manylinux2014_x86_64.manylinux_2_17_
Collecting scikit-learn
  Using cached scikit_learn-1.7.2-cp313-cp313-manylinux2014_x86_64.manylinux
Collecting matplotlib
  Using cached matplotlib-3.10.7-cp313-cp313-manylinux2014_x86_64.manylinux_
Collecting absl-py≥1.0.0 (from tensorflow)
  Downloading absl_py-2.3.1-py3-none-any.whl.metadata (3.3 kB)
Collecting astunparse≥1.6.0 (from tensorflow)
  Downloading astunparse-1.6.3-py2.py3-none-any.whl.metadata (4.4 kB)
Collecting flatbuffers≥24.3.25 (from tensorflow)
  Downloading flatbuffers-25.9.23-py2.py3-none-any.whl.metadata (875 bytes)
Collecting gast≠0.5.0,≠0.5.1,≠0.5.2,≥0.2.1 (from tensorflow)
  Downloading gast-0.6.0-py3-none-any.whl.metadata (1.3 kB)
Collecting google_pasta≥0.1.1 (from tensorflow)
  Downloading google_pasta-0.2.0-py3-none-any.whl.metadata (814 bytes)
Collecting libclang≥13.0.0 (from tensorflow)
  Downloading libclang-18.1.1-py2.py3-none-manylinux2010_x86_64.whl.metadata
Collecting opt_einsum≥2.3.2 (from tensorflow)
  Downloading opt_einsum-3.4.0-py3-none-any.whl.metadata (6.3 kB)
Collecting packaging (from tensorflow)
  Using cached packaging-25.0-py3-none-any.whl.metadata (3.3 kB)
Collecting protobuf≥5.28.0 (from tensorflow)
  Downloading protobuf-6.33.1-cp39-abi3-manylinux2014_x86_64.whl.metadata (5
Collecting requests<3,≥2.21.0 (from tensorflow)
  Using cached requests-2.32.5-py3-none-any.whl.metadata (4.9 kB)
Collecting setuptools (from tensorflow)
  Downloading setuptools-80.9.0-py3-none-any.whl.metadata (6.6 kB)
Collecting six≥1.12.0 (from tensorflow)
  Using cached six-1.17.0-py2.py3-none-any.whl.metadata (1.7 kB)
Collecting termcolor≥1.1.0 (from tensorflow)
```

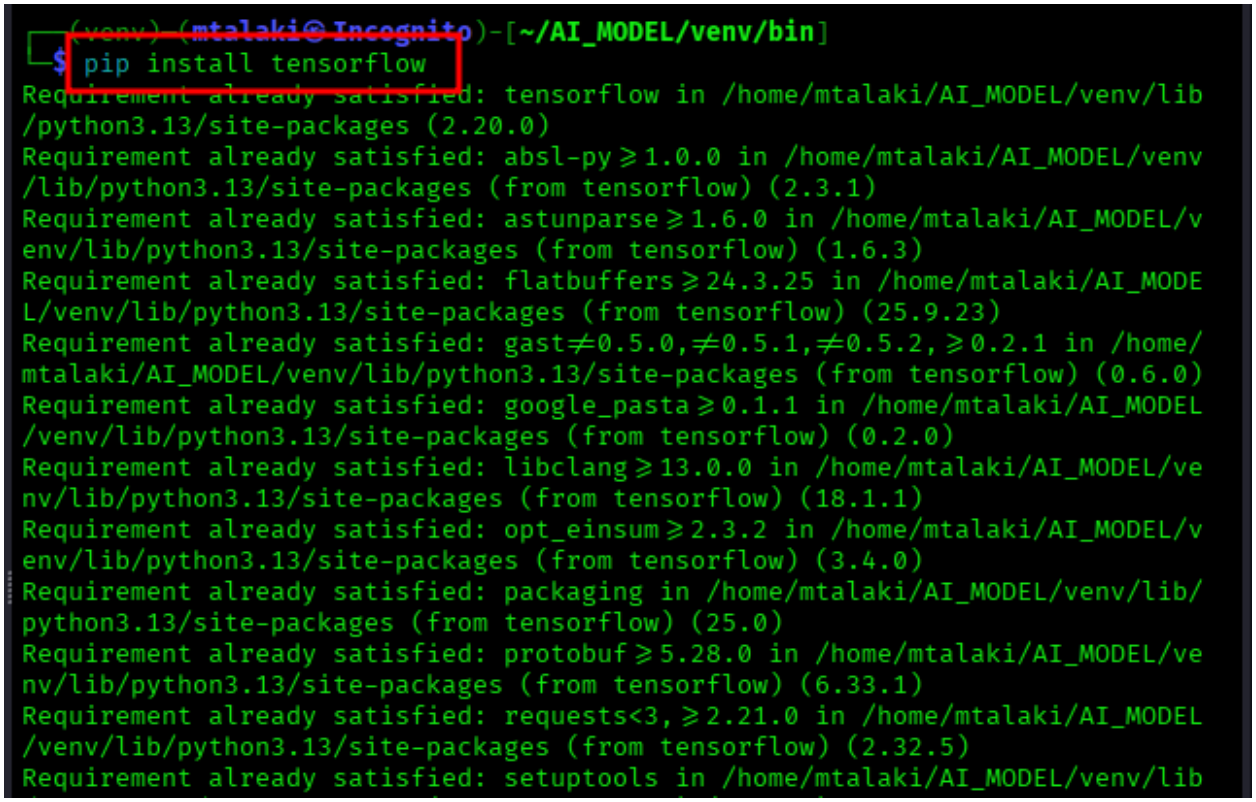
```
36/38 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step - accuracy: 1.0000 - loss: 1.3265e-0
38/38 ━━━━━━━━━━━━━━━━━━━━ 0s 29ms/step - accuracy: 1.0000 - loss: 1.2950e-0
38/38 ━━━━━━━━━━━━━━━━━━━━ 1s 33ms/step - accuracy: 1.0000 - loss: 7.2429e-0
6 - val_accuracy: 1.0000 - val_loss: 2.7815e-09
Epoch 50/50
 1/38 ━━━━━━━━━━━━━━━━━━━━ 1s 53ms/step - accuracy: 1.0000 - loss: 7.3760e-0
 3/38 ━━━━━━━━━━━━━━━━━━━━ 1s 32ms/step - accuracy: 1.0000 - loss: 6.8359e-0
 5/38 ━━━━━━━━━━━━━━━━━━━━ 1s 32ms/step - accuracy: 1.0000 - loss: 6.5505e-0
 7/38 ━━━━━━━━━━━━━━━━━━━━ 1s 33ms/step - accuracy: 1.0000 - loss: 7.0855e-0
 9/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 8.9167e-0
11/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.0595e-0
13/38 ━━━━━━━━━━━━━━━━━━━━ 0s 33ms/step - accuracy: 1.0000 - loss: 1.1376e-0
15/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1791e-0
17/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1983e-0
19/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.2015e-0
21/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1931e-0
23/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1782e-0
25/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1593e-0
27/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1439e-0
29/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1353e-0
31/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1245e-0
33/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1153e-0
35/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1094e-0
37/38 ━━━━━━━━━━━━━━━━━━━━ 0s 32ms/step - accuracy: 1.0000 - loss: 1.1143e-0
38/38 ━━━━━━━━━━━━━━━━━━━━ 1s 35ms/step - accuracy: 1.0000 - loss: 1.3862e-0
6 - val_accuracy: 1.0000 - val_loss: 2.3842e-09

Evaluating model on test data...
Test Accuracy: 100.00%
WARNING:absl:You are saving your model as an HDF5 file via `model.save()` or
 `keras.saving.save_model(model)`. This file format is considered legacy. We
 recommend using instead the native Keras format, e.g. `model.save('my_model
.keras')` or `keras.saving.save_model(model, 'my_model.keras')`.

Model saved successfully as audio_classifier.h5

(venv)-(mtalaki㉿Incognito)-[~/AI_MODEL/venv/bin]
$
```

Installing tensorflow to convert the .h5 file into a file usable by the microcontroller


(venv) (mtalaki㉿Incognito)-[~/AI_MODEL/venv/bin]
$ pip install tensorflow
Requirement already satisfied: tensorflow in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (2.20.0)
Requirement already satisfied: absl-py ⩾ 1.0.0 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (2.3.1)
Requirement already satisfied: astunparse ⩾ 1.6.0 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers ⩾ 24.3.25 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (25.9.23)
Requirement already satisfied: gast ≠ 0.5.0, ≠ 0.5.1, ≠ 0.5.2, ⩾ 0.2.1 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (0.6.0)
Requirement already satisfied: google_pasta ⩾ 0.1.1 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (0.2.0)
Requirement already satisfied: libclang ⩾ 13.0.0 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (18.1.1)
Requirement already satisfied: opt_einsum ⩾ 2.3.2 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (3.4.0)
Requirement already satisfied: packaging in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (25.0)
Requirement already satisfied: protobuf ⩾ 5.28.0 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (6.33.1)
Requirement already satisfied: requests<3, ⩾ 2.21.0 in /home/mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (2.32.5)
Requirement already satisfied: setuptools in /home/mtalaki/AI_MODEL/venv/lib

```
┌──(venv)─(mtalaki㉿Incognito)-[~/AI_MODEL/venv/bin]
└─$ pip install tensorflow
Requirement already satisfied: tensorflow in /home/mtalaki/AI_MODEL/venv/lib
/python3.13/site-packages (2.20.0)
Requirement already satisfied: absl-py≥1.0.0 in /home/mtalaki/AI_MODEL/venv
/lib/python3.13/site-packages (from tensorflow) (2.3.1)
Requirement already satisfied: astunparse≥1.6.0 in /home/mtalaki/AI_MODEL/v
env/lib/python3.13/site-packages (from tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers≥24.3.25 in /home/mtalaki/AI_MODE
L/venv/lib/python3.13/site-packages (from tensorflow) (25.9.23)
Requirement already satisfied: gast≠0.5.0,≠0.5.1,≠0.5.2,≥0.2.1 in /home/
mtalaki/AI_MODEL/venv/lib/python3.13/site-packages (from tensorflow) (0.6.0)
Requirement already satisfied: google_pasta≥0.1.1 in /home/mtalaki/AI_MODEL
/venv/lib/python3.13/site-packages (from tensorflow) (0.2.0)
Requirement already satisfied: libclang≥13.0.0 in /home/mtalaki/AI_MODEL/ve
nv/lib/python3.13/site-packages (from tensorflow) (18.1.1)
Requirement already satisfied: opt_einsum≥2.3.2 in /home/mtalaki/AI_MODEL/v
env/lib/python3.13/site-packages (from tensorflow) (3.4.0)
Requirement already satisfied: packaging in /home/mtalaki/AI_MODEL/venv/lib/
python3.13/site-packages (from tensorflow) (25.0)
Requirement already satisfied: protobuf≥5.28.0 in /home/mtalaki/AI_MODEL/ve
nv/lib/python3.13/site-packages (from tensorflow) (6.33.1)
Requirement already satisfied: requests<3,≥2.21.0 in /home/mtalaki/AI_MODEL
/venv/lib/python3.13/site-packages (from tensorflow) (2.32.5)
Requirement already satisfied: setuptools in /home/mtalaki/AI_MODEL/venv/lib
/python3.13/site-packages (from tensorflow) (80.9.0)
Requirement already satisfied: six≥1.12.0 in /home/mtalaki/AI_MODEL/venv/li
b/python3.13/site-packages (from tensorflow) (1.17.0)
Requirement already satisfied: termcolor≥1.1.0 in /home/mtalaki/AI_MODEL/ve
nv/lib/python3.13/site-packages (from tensorflow) (3.2.0)
Requirement already satisfied: typing_extensions≥3.6.6 in /home/mtalaki/AI_
MODEL/venv/lib/python3.13/site-packages (from tensorflow) (4.15.0)
Requirement already satisfied: wrapt≥1.11.0 in /home/mtalaki/AI_MODEL/venv/
lib/python3.13/site-packages (from tensorflow) (2.0.1)
Requirement already satisfied: grpcio<2.0,≥1.24.3 in /home/mtalaki/AI_MODEL
/venv/lib/python3.13/site-packages (from tensorflow) (1.76.0)
```

Deploy to ESP32;
The audio_classifier.h5 file created is a standard Keras/TensorFlow model. To use it on a resource-constrained device like an ESP32, it must be converted to TensorFlow Lite for Microcontrollers (TFLM) format.
The conversion process involves:

Quantization: Converting the model's 32-bit floating-point weights to 8-bit integers. This drastically reduces the model's size and makes it run much faster on microcontrollers.
Conversion: Using the TensorFlow Lite Converter to create a .tflite file.

```
(venv) (meetaki㉿Inspiron) [~/AI_MODEL/venv/bin]
└─$ python3 converter_model.py
2025-11-24 22:36:51.650955: I external/local_xla/xla/tsl/cuda/cud
art_stub.cc:31] Could not find cuda drivers on your machine, GPU
will not be used.
2025-11-24 22:36:52.822044: I tensorflow/core/platform/cpu_featur
e_guard.cc:210] This TensorFlow binary is optimized to use availa
ble CPU instructions in performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operatio
ns, rebuild TensorFlow with the appropriate compiler flags.
2025-11-24 22:36:55.872377: I external/local_xla/xla/tsl/cuda/cud
art_stub.cc:31] Could not find cuda drivers on your machine, GPU
will not be used.
Loading model from audio_classifier.h5 ...
2025-11-24 22:36:58.070070: E external/local_xla/xla/stream_execu
tor/cuda/cuda_platform.cc:51] failed call to cuInit: INTERNAL: CU
DA error: Failed call to cuInit: UNKNOWN ERROR (303)
WARNING:absl:Compiled the loaded model, but the compiled metrics
have yet to be built. `model.compile_metrics` will be empty until
 you train or evaluate the model.
Model loaded successfully.

Model: "sequential"
```

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 13, 32, 32)	320
batch_normalization (BatchNormalization)	(None, 13, 32, 32)	128
max_pooling2d (MaxPooling2D)	(None, 6, 16, 32)	0
dropout (Dropout)	(None, 6, 16, 32)	0
conv2d_1 (Conv2D)	(None, 6, 16, 64)	18,496