Hochschule Emden/Leer
Department of Electrical and Computer Engineering
Industrial Informatics

University of Applied Sciences
HOCHSCHULE EMDEN·LEER

Tensorflow Lite

Machine Learning framework

Manoj Selvaraju

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TensorFlow Lite I

Overview

- What is TensorFlow Lite?
  - TensorFlow Lite is a lightweight version of TensorFlow, which is an open-source machine learning framework developed by Google.
  - TensorFlow Lite is specifically designed for mobile and edge devices, allowing machine learning models to run efficiently on smartphones, embedded systems, and other devices with limited computational resources.
  - TensorFlow Lite optimizes machine learning models for deployment on these devices by providing tools for model conversion, model optimization, and inference.

Benefits of TensorFlow Lite I

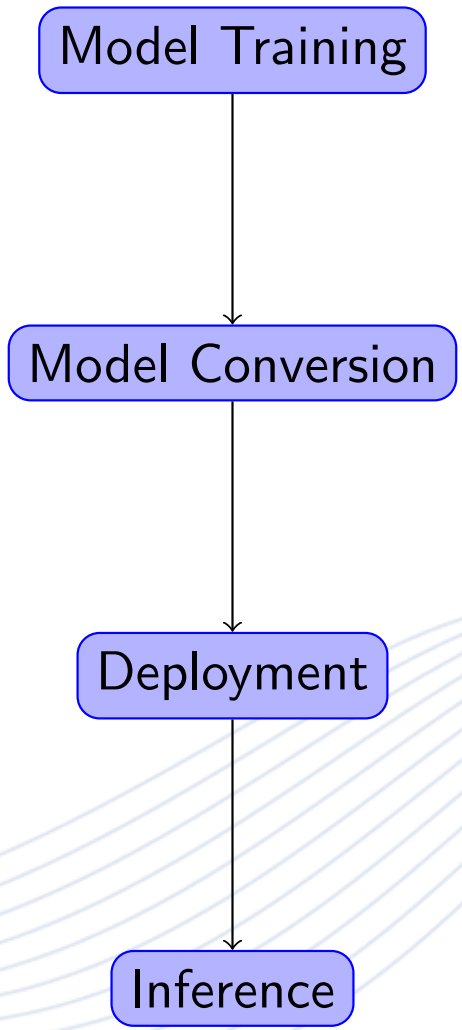
Key benefits

- Low Latency: Faster inference on-device.
- Reduced Size: Smaller model and binary sizes suitable for devices with limited resources.
- For common machine learning tasks such as image classification, object detection, pose estimation, question answering, text classification, etc. on multiple platforms.

Core Components of TensorFlow Lite I

- Interpreter: Executes the model.
- Converter: Converts TensorFlow models into a compressed flat buffer format.
- Supported Ops: Set of operations optimized for mobile and embedded devices.

TensorFlow Lite Working I



TensorFlow Lite Working I

Step-by-Step working

1. Model Training:
   - Train a model using TensorFlow on a desktop or cloud environment.
2. Model Conversion:
   - Convert the trained model to TFLite format (.tflite) using the TFLite Converter
3. Deployment:
   - Deploy the TFLite model on mobile, embedded, or IoT devices.
4. Inference:
   - Run the model using TFLite Interpreter to perform predictions on the device.

TensorFlow Lite Model Conversion I

- **TFLite Converter**:
  - The TensorFlow Lite converter takes a TensorFlow model and generates a TensorFlow Lite model (an optimized FlatBuffer format identified by the .tflite file extension)
  - You can convert your model using the Python API or the Command line tool
  - Command-line Tool: `tflite_convert`
  - Python API: `tf.lite.TFLiteConverter`
- **Optimization Techniques**:
  To make machine learning models more efficient for deployment on mobile and edge devices
  - **Quantization**: Reduces model size and latency.
  - **Pruning:** Removes unnecessary parts of the model.
  - **Clustering:** Groups similar weights to reduce model complexity.

TFLite Interpreter I

1. **Loading Model**
   - Load the TFLite model onto the device.
2. **Allocating Tensors**
   - Allocate memory for input and output tensors.
3. **Setting Input Tensors**
   - Set input tensor values with data for inference.
4. **Running Inference**
   - Execute the model with input data.
5. **Getting Output Tensors**
   - Retrieve output tensor values for results.

NOTE: A tensor refers to a multi-dimensional array or a generalized vector. It represents the basic unit of data in TensorFlow Lite and is used to store input data, intermediate calculations, and output predictions

Code

```
import tensorflow as tf
# Load TFLite model and allocate tensors.
interpreter = tf.lite.Interpreter(model_path=
                                  "model.tflite")
interpreter.allocate_tensors()
# Get input and output tensors.
input_details = interpreter.get_input_details()
output_details = interpreter.get_output_details()
# Set the value of the input tensor.
interpreter.set_tensor(input_details[0]['index'],
                       input_data)

# Run the model.
interpreter.invoke()
# Get the value of the output tensor.
output_data = interpreter.get_tensor(output_details[0]
                                     ['index'])
```

Getting started with TensorFlow Lite in Portenta H7 using Arduino IDE

Tensorflow Lite Installation on PC I

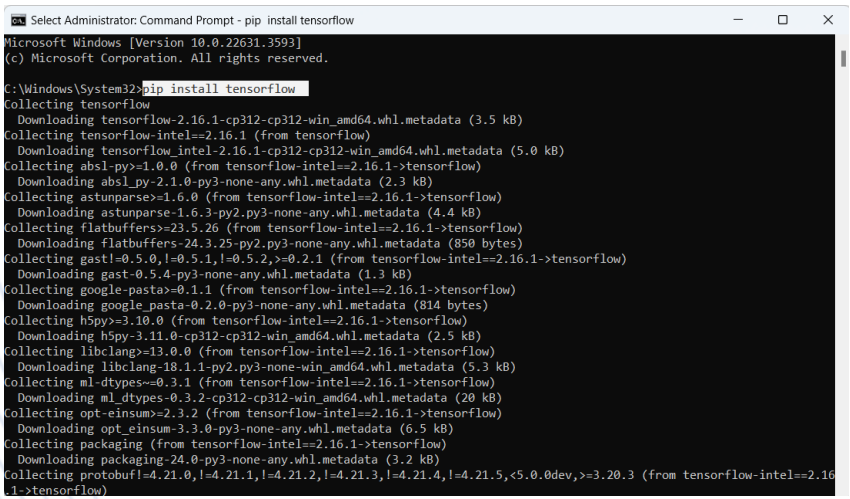


Figure1: TensorFlow Installation

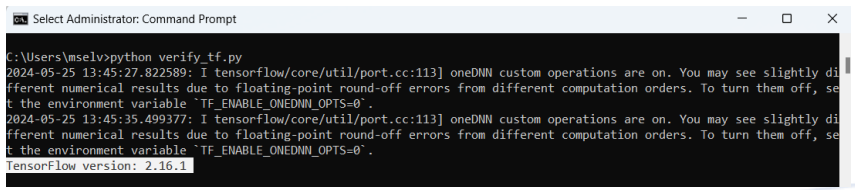


Figure2: TensorFlow Version

Tensorflow Lite Library Installation on Arduino IDE I

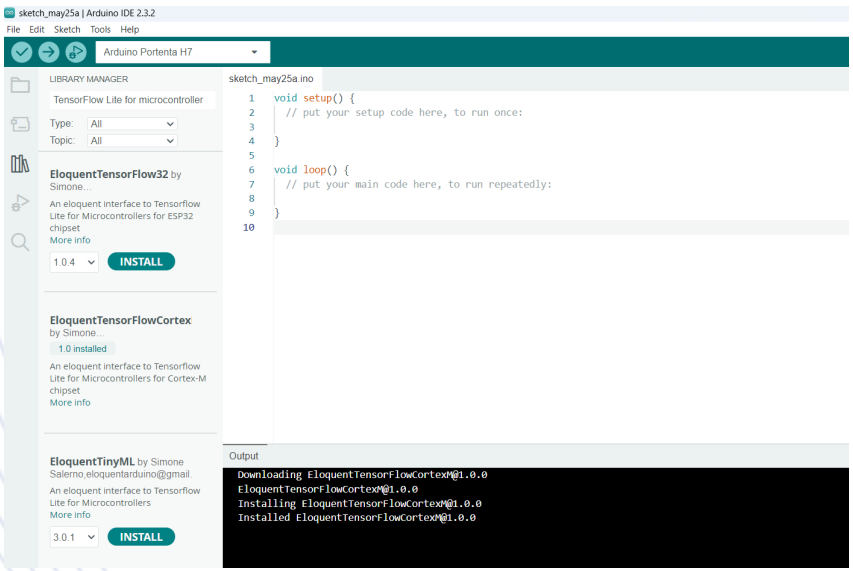


Figure1: TensorFlow Cortex Library

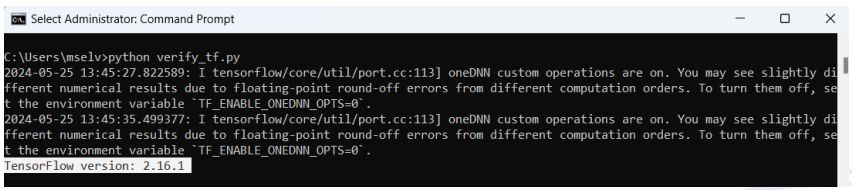


Figure2: TensorFlow Version

TensorFlow Model Training

```python
import tensorflow as tf
import numpy as np
input_shape = (2,) # Define the input shape
model = tf.keras.Sequential([ # Create a Seq.model
    tf.keras.layers.Input(shape=input_shape),
    tf.keras.layers.Dense(1)  # Single neuron for o/p
])
# Compile the model
model.compile(optimizer='sgd', loss='mse')
# Generate some training data
X_train = np.array([[1, 2], [3, 4], [5, 6]])
y_train = np.array([[3], [7], [11]])
# Train the model
model.fit(X_train, y_train, epochs=100, verbose=0)
# Save the model using recommended method for TF 2.x
tf.keras.models.save_model(model, 'addition_model.h5')
print("Model saved as 'addition_model.h5'")
```

Listing 1: Python code for training a TensorFlow model

STEPS I

1. Train a simple Keras model in TensorFlow and run the model in python to generate the file `addition_model.h5` in the same directory of tensorflow model.
2. Convert the Keras Model to TensorFlow Lite using the python script in the same directory and run the command `python convertModelTotflite.py` in command prompt
3. Using the python script convert the TensorFlow Lite Model to a C Array and run the python `ConvertTfliteToHeader.py` in the command prompt
4. Now include the model in the Arduino Sketch and run it on the Portenta H7.

TF Model to TF Lite

```python
import tensorflow as tf
from tensorflow.keras.losses import MeanSquaredError
# Load the Keras model with custom objects
model = tf.keras.models.load_model('addition_model.h5', custom_objects={'mse': MeanSquaredError()})
# Create a concrete function from the Keras model
@tf.function(input_signature=[tf.TensorSpec(shape=[None, 2], dtype=tf.float32)])
def model_concrete_func(x):
    return model(x)
# Convert the concrete fn to a TF Lite model
converter = tf.lite.TFLiteConverter.from_concrete_functions([model_concrete_func.get_concrete_function()])
tflite_model = converter.convert()
# Save the TensorFlow Lite model to a file
with open('addition_model.tflite', 'wb') as f:
    f.write(tflite_model)
```

Listing 2: Python code to convert keras model to tflite

TF Lite Model to C Array Header

```python
import numpy as np # convert_tflite_to_header.py
with open("addition_model.tflite", "rb") as f:
    tflite_model = f.read()
tflite_model_as_c_array = np.array(list(tflite_model),
    dtype=np.uint8)
with open("addition_model.h", "w") as f:
    f.write("#ifndef ADDITION_MODEL_H\n")
    f.write("#define ADDITION_MODEL_H\n\n")
    f.write("unsigned char addition_model_tflite[] = {
        ")
    for i, byte in enumerate(tflite_model_as_c_array):
        if i % 12 == 0:
            f.write("\n")
        f.write(f"0x{byte:02x}, ")
    f.write("\n};\n\n")
    f.write("unsigned int addition_model_tflite_len =
        {};\n".format(len(tflite_model_as_c_array)))
    f.write("#endif // ADDITION_MODEL_H\n")
```

Listing 3: Python code to convert Tensorflow Lite model to C Array

Arduino Sketch to run the model

```
#include <TensorFlowLite.h>
#include <Arduino_TensorFlowLite.h>

// Include the TensorFlow Lite model
#include "simple_addition_model.h" // Assuming this is y

void setup() {
        // Initialize serial communication
        Serial.begin(9600);

        // Initialize TensorFlow Lite interpreter
        if (!TfLite.begin(model_data, model_data_size))
                Serial.println("Failed to initialize Ten
                while (1);
        }
}
```

Arduino Sketch to run the model

```
void loop() {
        // Example inference
        float input1 = 5.0;
        float input2 = 3.0;

        // Prepare input tensor
        TfLiteTensor* input = TfLite.getInputTensor(0);
        input->data.f[0] = input1;
        input->data.f[1] = input2;

        // Run inference
        TfLite.run();

        // Get output tensor
        TfLiteTensor* output = TfLite.getOutputTensor(0)
        float result = output->data.f[0];
```

Arduino Sketch to run the model

```
    // Print result
    Serial.print(input1);
    Serial.print("+");
    Serial.print(input2);
    Serial.print("=");
    Serial.println(result);

    // Wait
    delay(1000);
}
```

Thank you

for your attention

Quellen I

Bibliography / References

[Ten24] TensorflowLite. *TensorflowLite 2024*. 2024. URL: https://www.tensorflow.org/lite.