IESTI05 – Edge AI

Machine Learning System Engineering

5. Image Classification: Introduction to TFLite Runtime

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Computer Vision Recognition Tasks

Image Classification

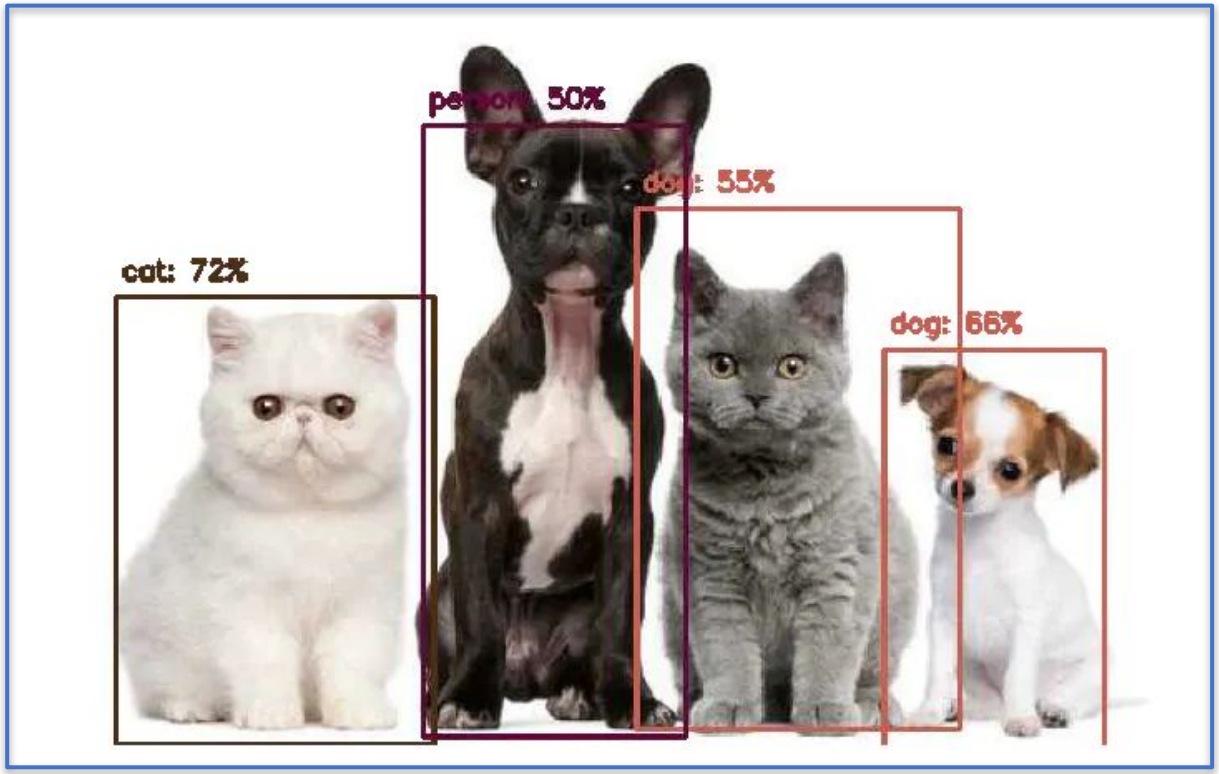
(**Multi-Class** Classification)

Cat: 70%

Dog: 80%

Object Detection

Multi-Label Classification + Object **Localization**



Computer Vision Recognition Tasks

Instance Segmentation

Each pixel in an image IS CLASSIFIED into a predefined category.

Pose Estimation

Key points (or landmarks) on the object, such as joints on a human body are detect

Image Classification

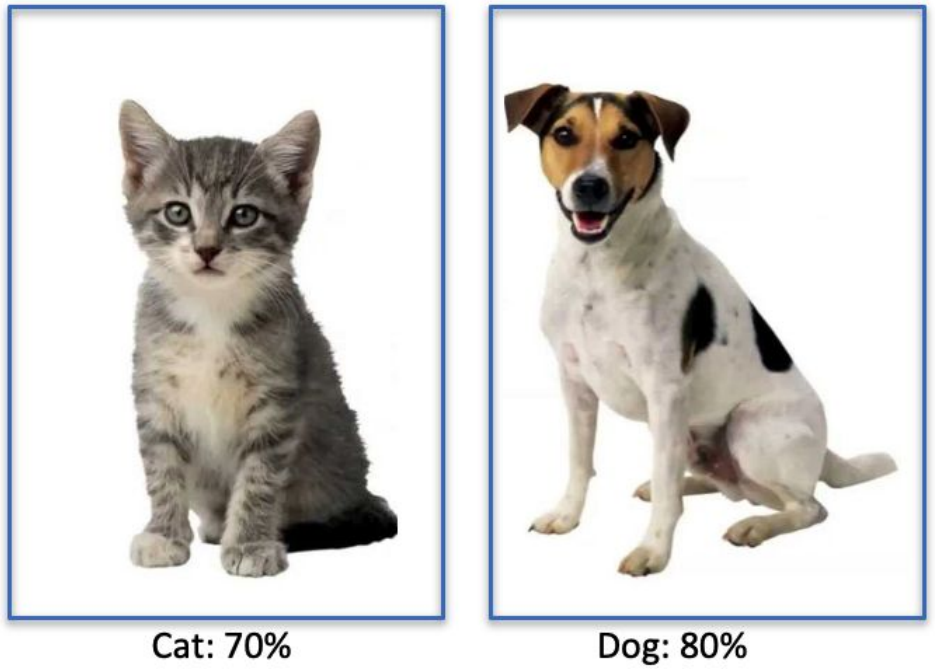
What is Image Classification?

Definition

Image classification is a fundamental task in computer vision that involves **categorizing an image into one of several predefined classes**.

Key Characteristics

- Assigns a single label to the entire image
- Based on visual content analysis
- Uses machine learning algorithms
- Mimics human visual perception



Real-World Applications

🏥 Healthcare

Medical image analysis, X-ray and MRI diagnostics

🌾 Agriculture

Crop health monitoring, disease detection

🚗 Automotive

Autonomous vehicles, road sign recognition

🔒 Security

Surveillance systems, threat detection

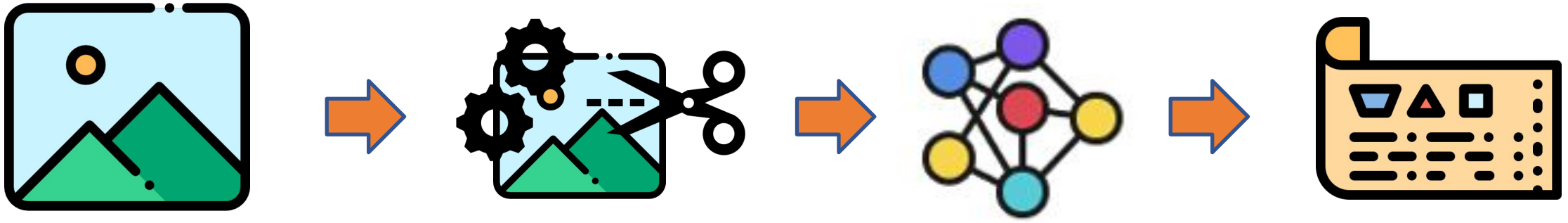
🛒 Retail

Visual search, inventory management

🌍 Environmental

Satellite imagery analysis, monitoring

Image Classification: Inference Pipeline



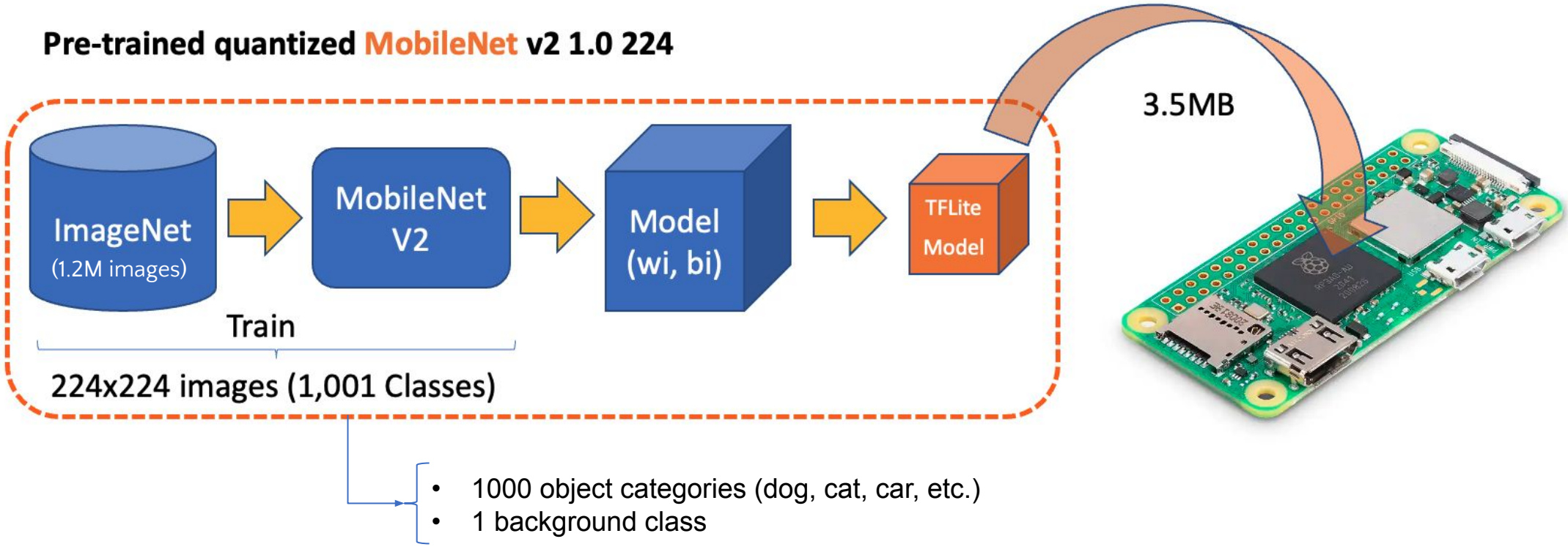
Input Image

Pre-Process

Classification Model

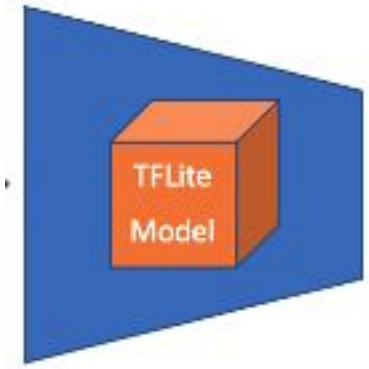
Predict Label

The MobileNet V2 model



- 1000 object categories (dog, cat, car, etc.)
- 1 background class

TFLite Interpreter




```
input_details
```

```
[{'name': 'input',
  'index': 171,
  'shape': array([  1, 224, 224,   3], dtype=int32),
  'shape_signature': array([  1, 224, 224,   3], dtype=int32),
  'dtype': numpy.uint8,
  'quantization': (0.0078125, 128),
  'quantization_parameters': {'scales': array([0.0078125], dtype=float32),
   'zero_points': array([128], dtype=int32),
   'quantized_dimension': 0},
  'sparsity_parameters': {}}]
```

Input Image Shape Signature

Pixel data type

Quantization Parameters

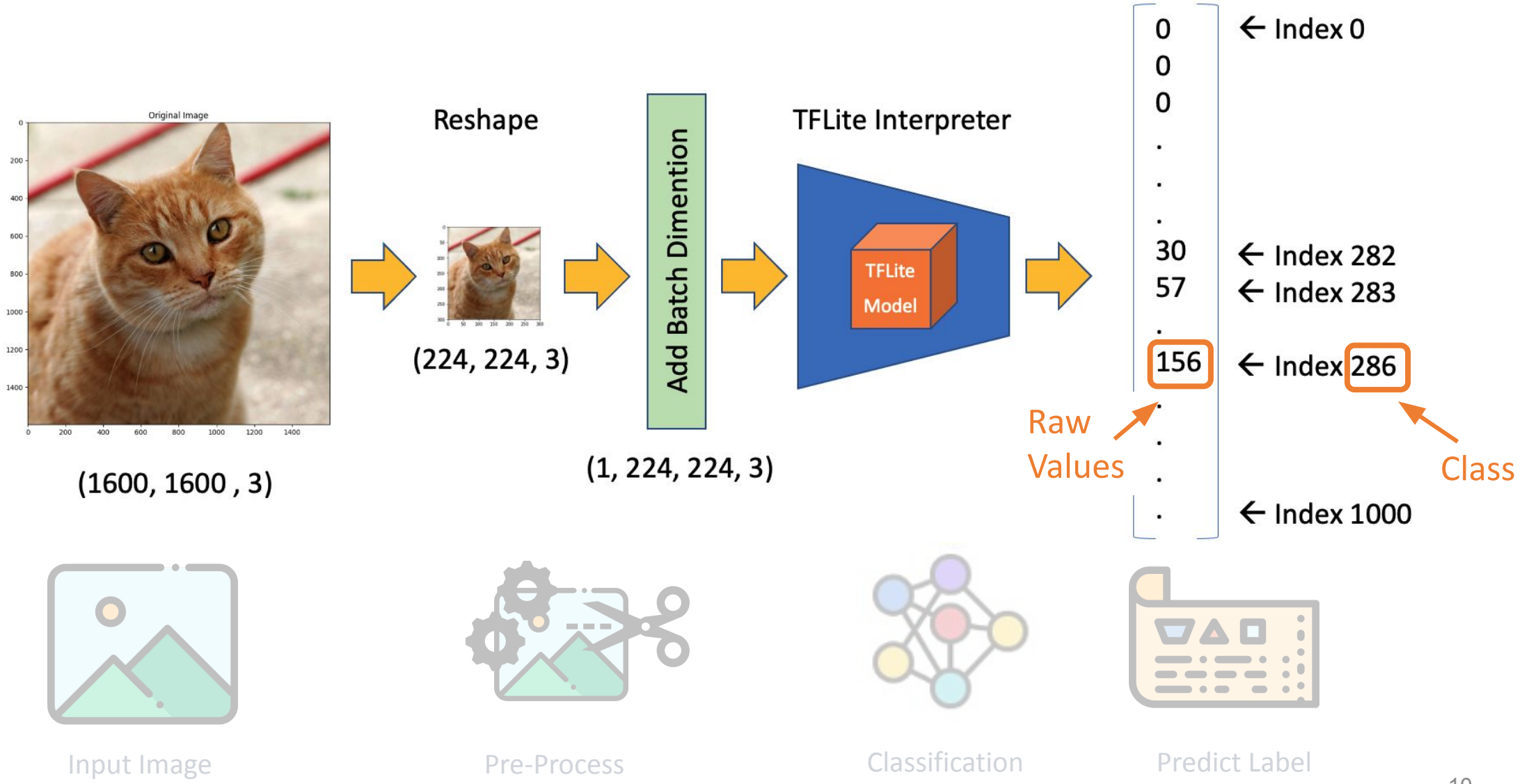
```
output_details
```

```
[{'name': 'output',
  'index': 172,
  'shape': array([   1, 1001], dtype=int32),
  'shape_signature': array([   1, 1001], dtype=int32),
  'dtype': numpy.uint8,
  'quantization': (0.09889253973960876, 58),
  'quantization_parameters': {'scales': array([0.09889254], dtype=float32),
   'zero_points': array([58], dtype=int32),
   'quantized_dimension': 0},
  'sparsity_parameters': {}}]
```

Output model

Quant Dim 0: One set of parameters for the entire output tensor

Making inferences with MobileNet V2



TFLite Runtime

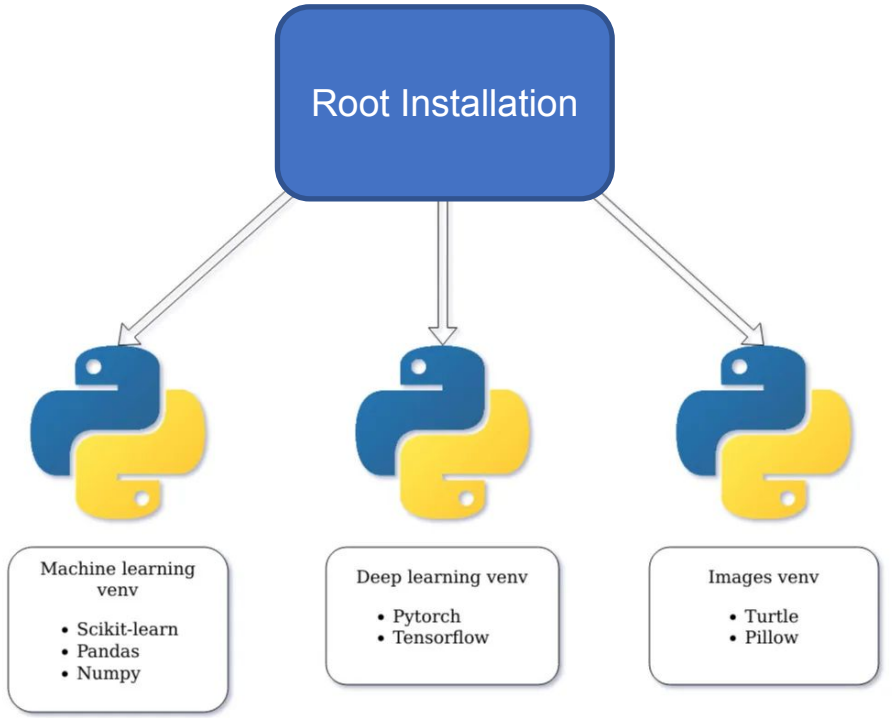
Setting up a Virtual Environment

Activate the environment:

```
source ~/tflite_env/bin/activate
```

To exit the virtual environment, use:

```
deactivate
```



TensorFlow Lite Setup

What is TensorFlow Lite?

A lightweight runtime for running machine learning models on mobile and embedded devices, optimized for inference with minimal latency.

We'll use the TensorFlow Lite runtime for Raspberry Pi, a simplified library for running machine learning models on mobile and embedded devices, without including all TensorFlow packages.

```
pip install tflite-runtime
```

tflite_runtime-2.14.0-cp311-cp311-manylinux_2_34_aarch64.whl

```
sudo reboot
```

Verify installation:

```
pip list | grep -E "(tflite-runtime)"
```

tflite-runtime 2.14.0.

Creating a working directory & get the model

```
Documents/
├── TFLITE/
│   └── IMG_CLASS/
│       ├── models/
│       │   ├── mobilenet_v2.tflite
│       │   └── labels.txt
│       └── images/
│           └── test_image.jpeg
```

Go to the models/ folder and get the Model and labels

```
wget https://storage.googleapis.com/download.tensorflow.org/models/tflite_11_05_08/mobilenet_v2_1.0_224_quant.tgz
```

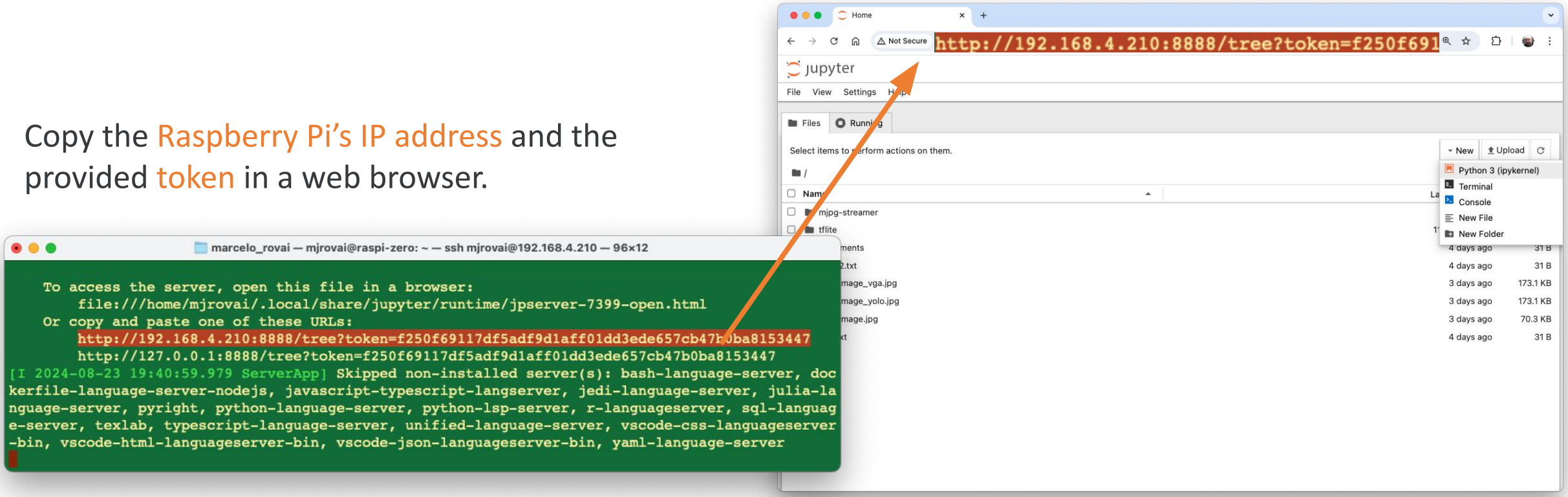
```
tar xzf mobilenet_v2_1.0_224_quant.tgz
```

```
wget https://raw.githubusercontent.com/Mjrovai/EdgeML-with-Raspberry-Pi/refs/heads/main/IMG_CLASS/models/labels.txt
```

Running up Jupyter Notebook

jupyter notebook --ip=[YOUR IP ADDREES] --no-browser

Copy the Raspberry Pi's IP address and the provided token in a web browser.



Verifying the Setup


```
import tflite_runtime.interpreter as tflite
import numpy as np
from PIL import Image

print("NumPy:", np.__version__)
print("Pillow:", Image.__version__)

# Try to create a TFLite Interpreter
model_path = "./models/mobilenet_v2_1.0_224_quant.tflite"
interpreter = tflite.Interpreter(model_path=model_path)
interpreter.allocate_tensors()
print("TFLite Interpreter created successfully!")
```

Raspberry Pi Inference:

10_Image_Classification.ipynb

Making inferences: Static Images and Camera

[PREDICTION]	[Prob]
tiger cat	: 37%
Egyptian cat	: 27%
tabby	: 16%
lynx	: 10%
carton	: 2%

[PREDICTION]	[Prob]
coffee mug	: 99%
cup	: 0%
whiskey jug	: 0%
teapot	: 0%
water jug	: 0%

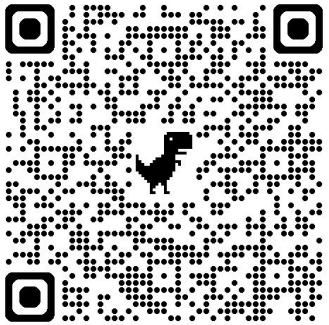
Optional

Training:

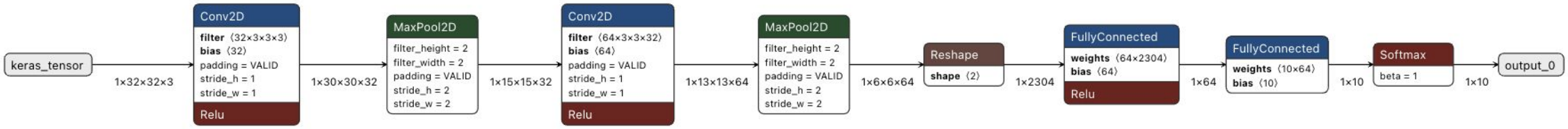
CNN model to classify the CIFAR-10 dataset

Raspberry Pi Inference:

20_Cifar_10_Image_Classification.ipynb



Cifar-10 - Inference




```
[PREDICTION]        [Prob]

dog                 : 45.0%
cat                 : 28.7%
bird                : 9.3%
horse               : 5.5%
truck               : 4.2%

Inference time: 2.8ms
```

```
[PREDICTION]        [Prob]

cat                 : 56.2%
dog                 : 24.9%
frog                : 14.3%
deer                : 2.2%
bird                : 1.9%

Inference time: 2.8ms
```

```
[PREDICTION]        [Prob]

ship                : 88.7%
airplane            : 9.2%
deer                : 1.8%
bird                : 0.2%
automobile          : 0.0%

Inference time: 2.8ms
```

```
[PREDICTION]        [Prob]

automobile          : 99.7%
truck               : 0.3%
airplane            : 0.0%
ship                : 0.0%
bird                : 0.0%

Inference time: 2.8ms
```

Questions?

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