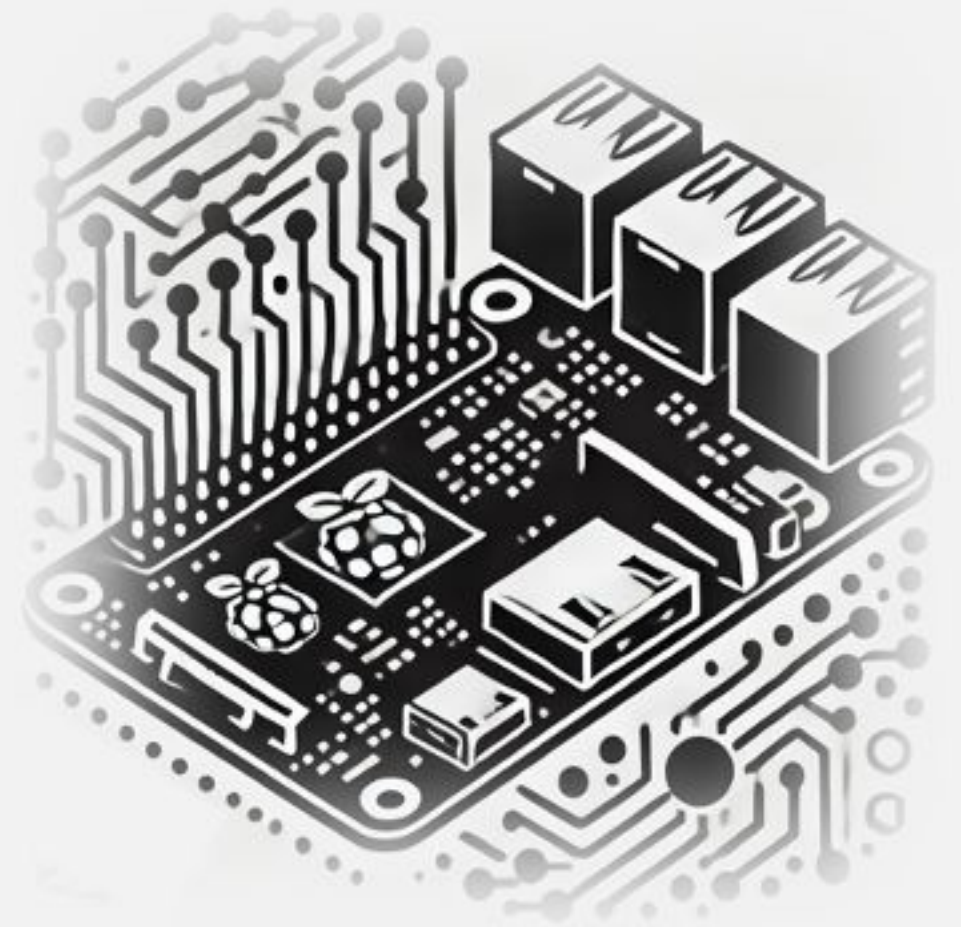


IESTI05 – Edge AI

Machine Learning System Engineering

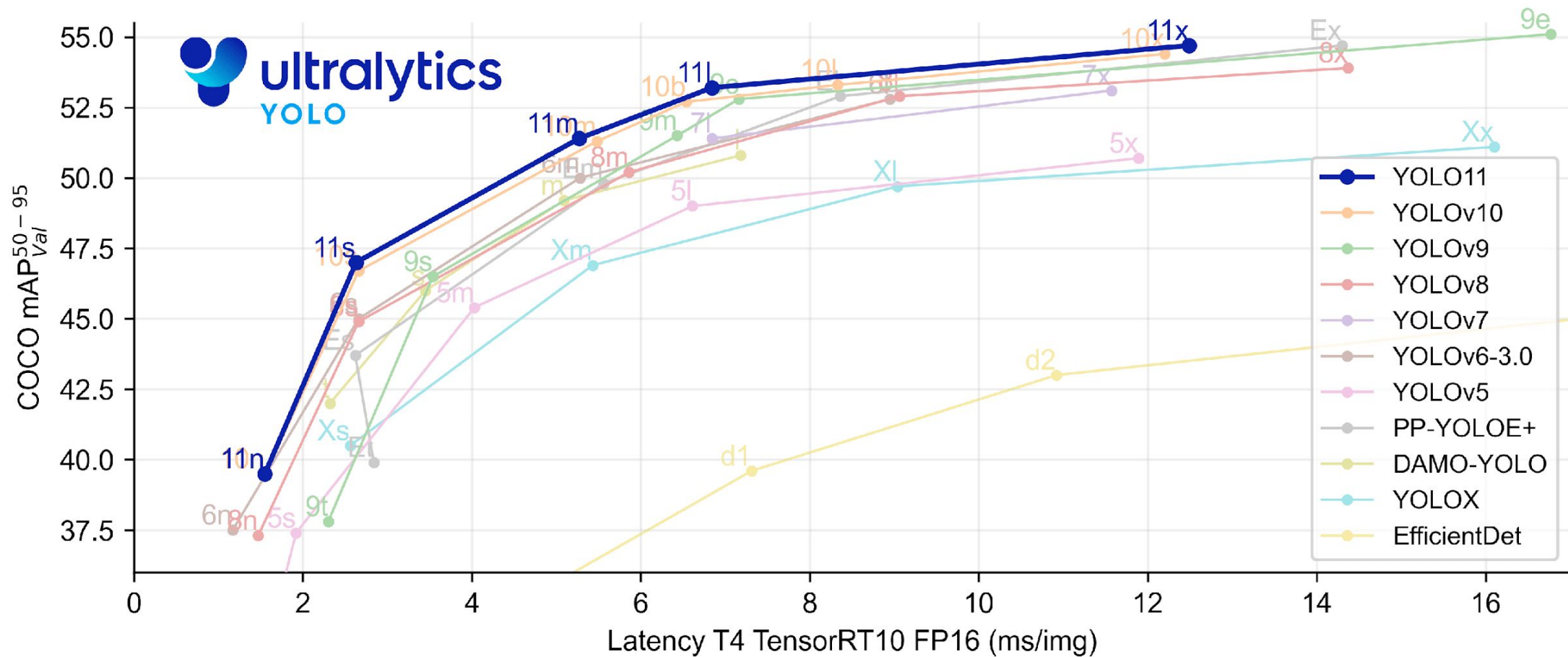
11. Object Detection with YOLO: Fundamentals



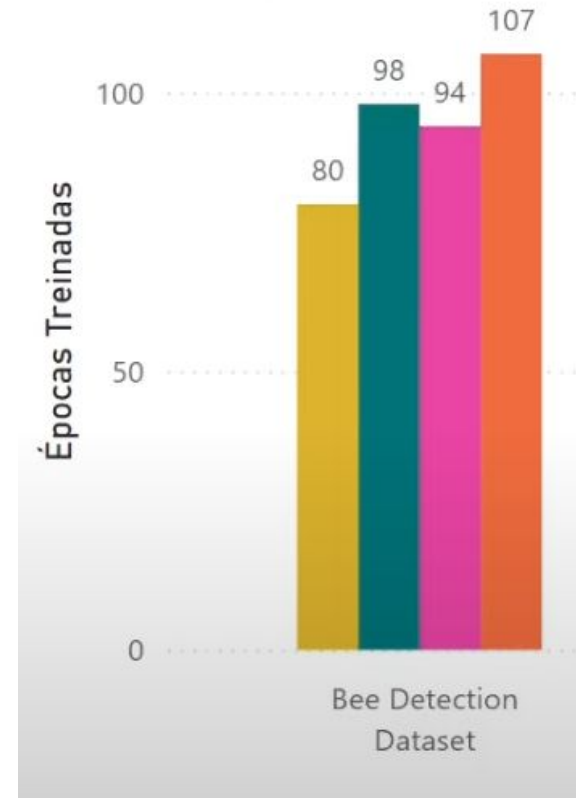
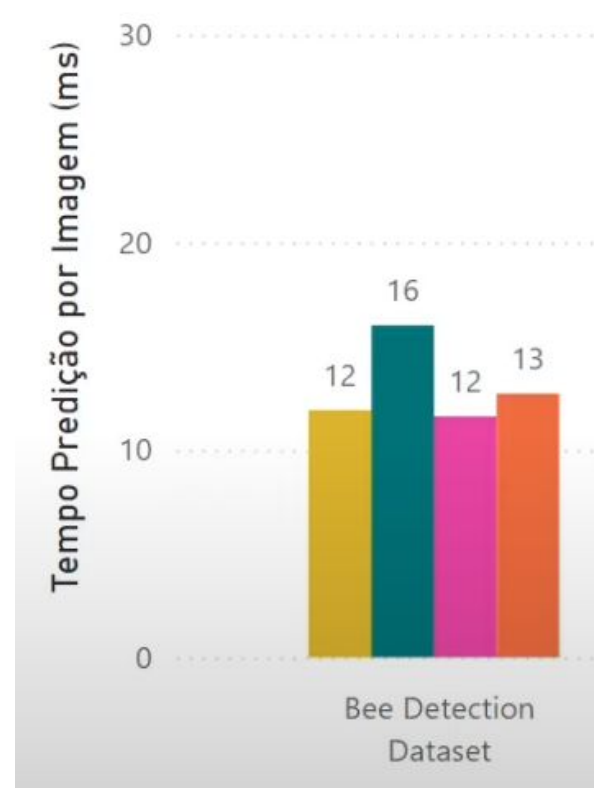
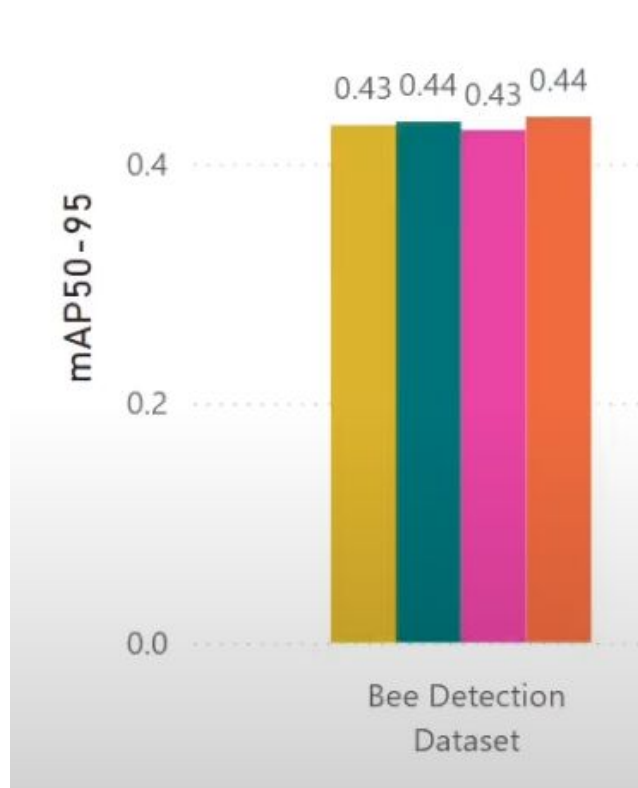
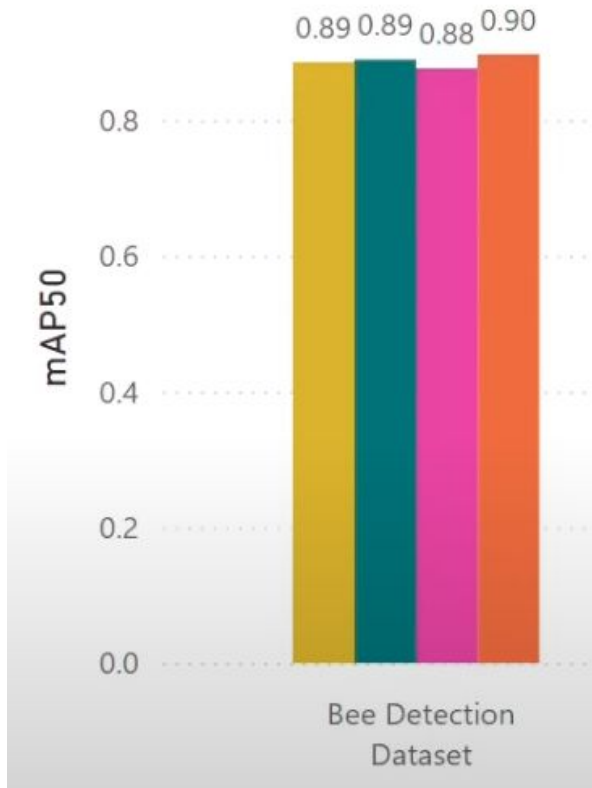
YOLO

Fundamentals

Ultralytics YOLO11



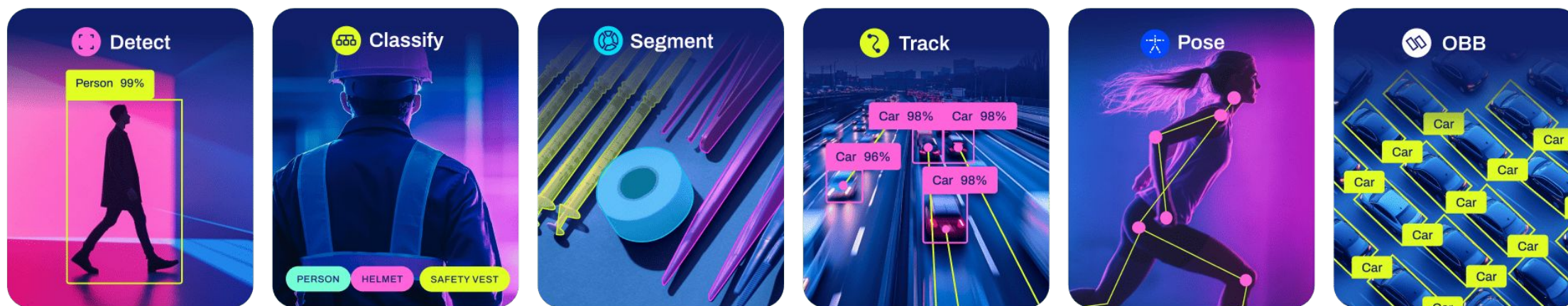
YOLO Versions Comparison



[Spreadsheet](#)

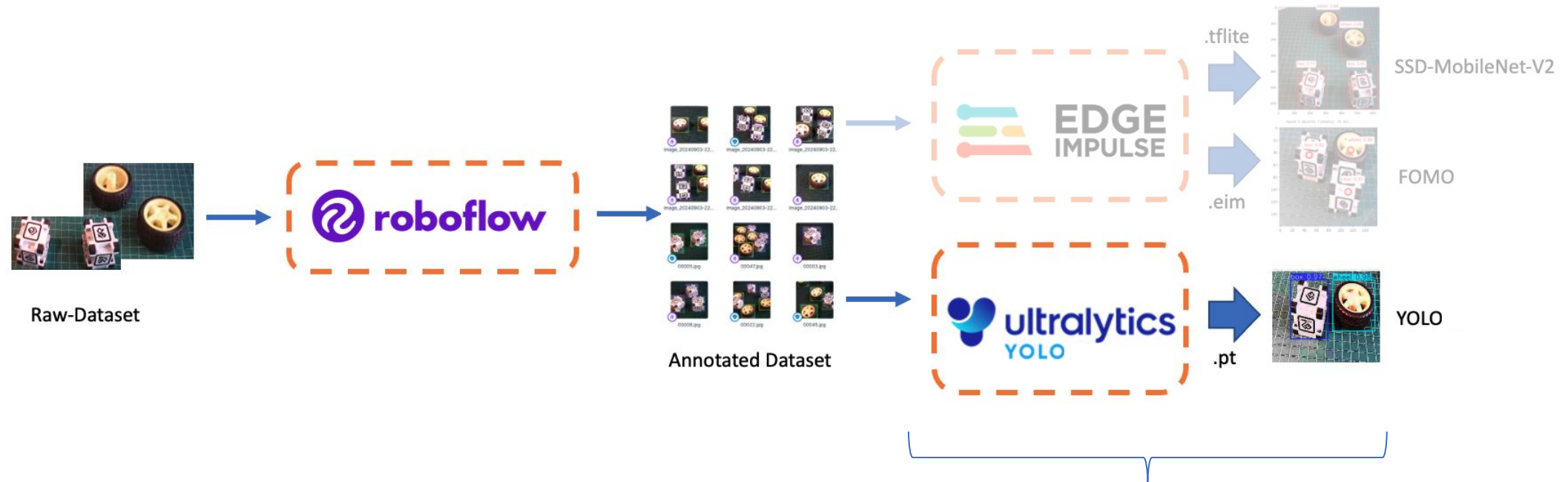
https://youtu.be/F8m0qo_gMbc?si=ADW8u6Q_yAM4GIY4

Ultralytics YOLO11

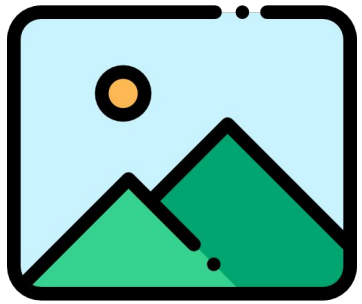


Oriented Bounding Boxes

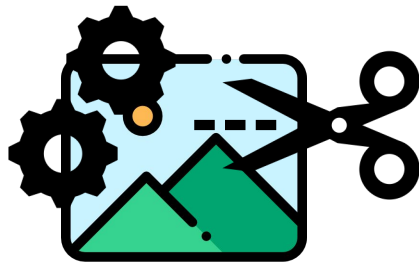
YOLO with Roboflow and Ultralytics



Object Detection: Inference Pipeline



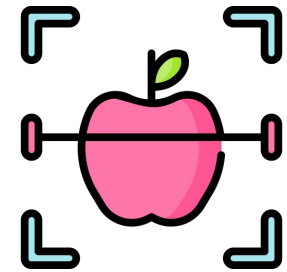
Input Image



Pre-Process



Detection
Model



Predict Labels
& Bounding Boxes

YOLOv11 - Ultralytics

Setting up a Virtual Environment

1. Create a **virtual environment** with access to system packages to manage dependencies:

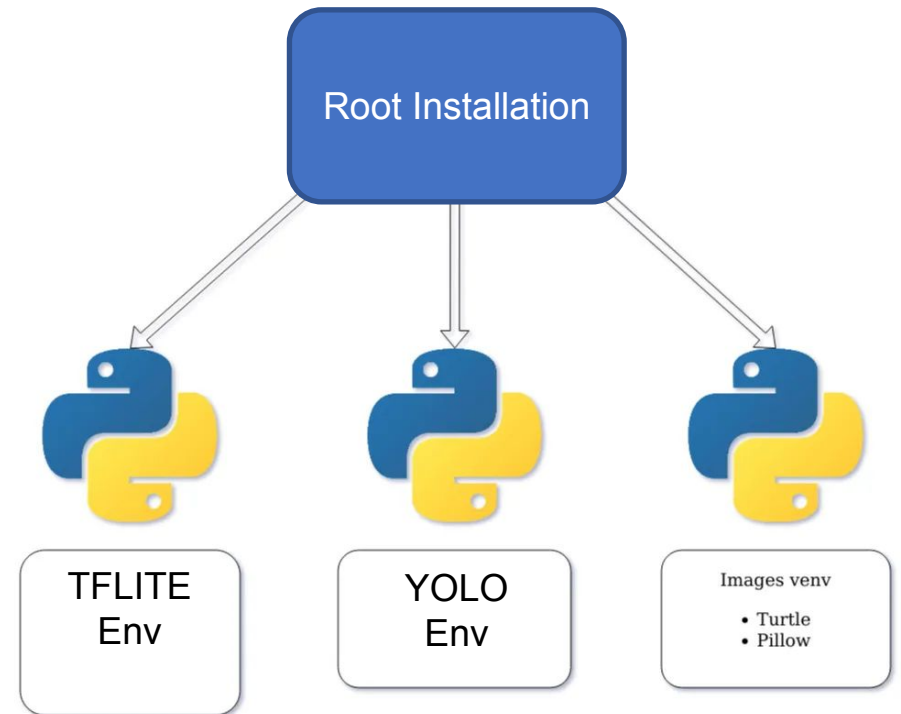
```
python3 -m venv ~/yolo --system-site-packages
```

2. **Activate** the environment:

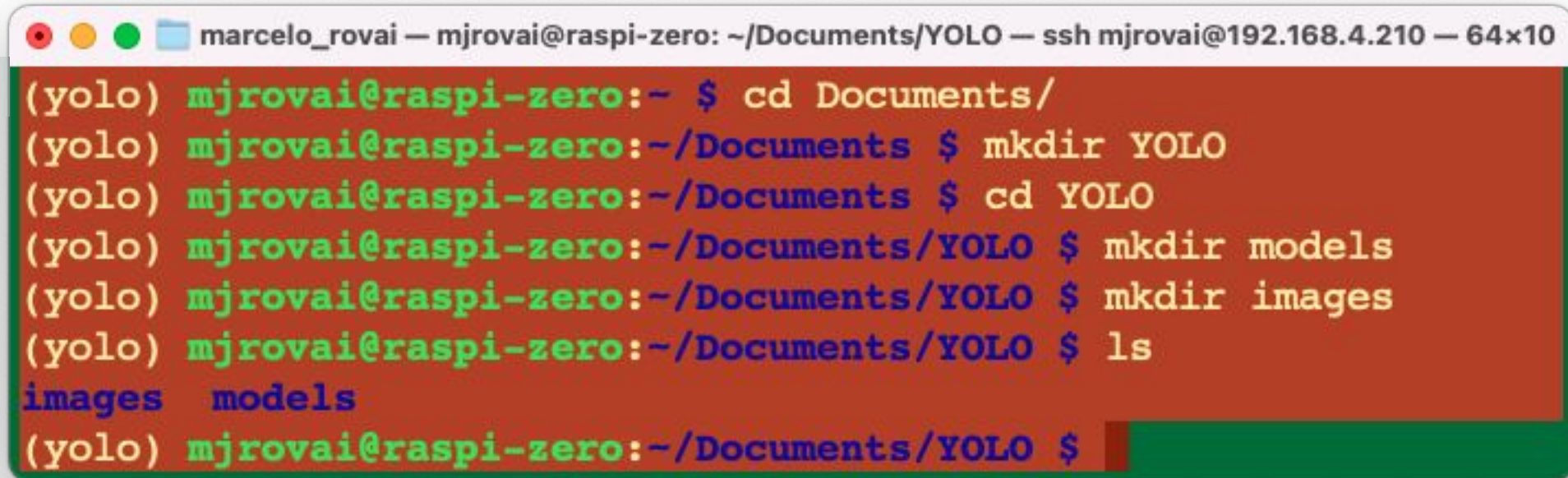
```
source ~/yolo/bin/activate
```

To **exit** the virtual environment, use:

```
deactivate
```



Creating a working directory

A terminal window with a title bar that reads "marcelo_rovai — mjrovai@raspi-zero: ~/Documents/YOLO — ssh mjrovai@192.168.4.210 — 64x10". The terminal has a dark red background and shows a series of commands and their outputs. The commands are: "cd Documents/", "mkdir YOLO", "cd YOLO", "mkdir models", "mkdir images", and "ls". The output of "ls" shows "images" and "models" on separate lines. The prompt for the final command is partially obscured by a green bar at the bottom of the terminal window.

```
(yolo) mjrovai@raspi-zero:~ $ cd Documents/  
(yolo) mjrovai@raspi-zero:~/Documents $ mkdir YOLO  
(yolo) mjrovai@raspi-zero:~/Documents $ cd YOLO  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ mkdir models  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ mkdir images  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ ls  
images  models  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $
```

Install the Ultralytics packages

- Update the packages list, install pip, and upgrade to the latest:
 - `sudo apt update`
 - `sudo apt install python3-pip -y`
 - `pip install -U pip`
- Install the ultralytics pip package with optional dependencies:
 - `pip install ultralytics[export]`
 - `sudo reboot`

Note: Installing Ultralytics packages takes several minutes

YOLOv11 versus v8 - Inference

```
marcelo_rovai — mjrovai@raspi-zero: ~/Documents/YOLO — ssh mjrovai@192.168.4.210 — 107x17
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ yolo predict model=yolo11n.pt source=bus.jpg
Ultralytics 8.3.191 🚀 Python-3.11.2 torch-2.8.0+cpu CPU (Cortex-A53)
YOLO11n summary (fused): 100 layers, 2,616,248 parameters, 0 gradients, 6.5 GFLOPs

image 1/1 /home/mjrovai/Documents/YOLO/bus.jpg: 640x480 4 persons, 1 bus, 3222.3ms
Speed: 186.6ms preprocess, 3222.3ms inference, 148.3ms postprocess per image at shape (1, 3, 640, 480)
Results saved to runs/detect/predict4
💡 Learn more at https://docs.ultralytics.com/modes/predict
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ yolo predict model='yolov8n' source='bus.jpg'
Ultralytics 8.3.191 🚀 Python-3.11.2 torch-2.8.0+cpu CPU (Cortex-A53)
YOLOv8n summary (fused): 72 layers, 3,151,904 parameters, 0 gradients, 8.7 GFLOPs

image 1/1 /home/mjrovai/Documents/YOLO/bus.jpg: 640x480 4 persons, 1 bus, 1 stop sign, 6870.6ms
Speed: 190.2ms preprocess, 6870.6ms inference, 157.0ms postprocess per image at shape (1, 3, 640, 480)
Results saved to runs/detect/predict5
💡 Learn more at https://docs.ultralytics.com/modes/predict
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $
```

Export Models to NCNN format

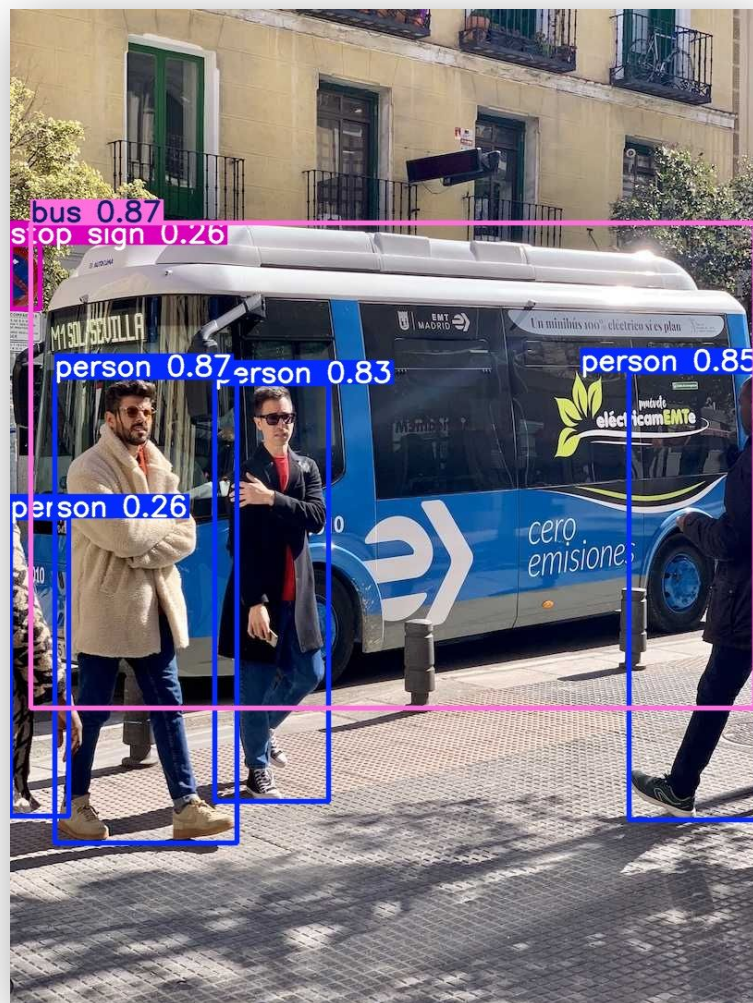
```
yolo export model=yolov8n.pt format=ncnn  
yolo export model=yolo11n.pt format=ncnn
```

```
marcelo_rovai — mjrovai@raspi-zero: ~/Documents/YOLO — ssh mjrovai@192.168.4.210 — 135x9  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ yolo predict task=detect model='./models/yolov8n_ncnn_model' source='./images/bus.jpg'  
Ultralytics 8.3.191 🚀 Python-3.11.2 torch-2.8.0+cpu CPU (Cortex-A53)  
Loading ./models/yolov8n_ncnn_model for NCNN inference...  
  
image 1/1 /home/mjrovai/Documents/YOLO/images/bus.jpg: 640x640 4 persons, 1 bus, 3566.8ms  
Speed: 484.4ms preprocess, 3566.8ms inference, 1519.0ms postprocess per image at shape (1, 3, 640, 640)  
Results saved to runs/detect/predict10  
💡 Learn more at https://docs.ultralytics.com/modes/predict  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $
```

```
marcelo_rovai — mjrovai@raspi-zero: ~/Documents/YOLO — ssh mjrovai@192.168.4.210 — 138x9  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $ yolo predict task=detect model=models/yolol1n_ncnn_model imgsz=640 source=./images/bus.jpg  
Ultralytics 8.3.191 🚀 Python-3.11.2 torch-2.8.0+cpu CPU (Cortex-A53)  
Loading models/yolol1n_ncnn_model for NCNN inference...  
  
image 1/1 /home/mjrovai/Documents/YOLO/images/bus.jpg: 640x640 4 persons, 1 bus, 1034.6ms  
Speed: 1764.9ms preprocess, 1034.6ms inference, 3406.3ms postprocess per image at shape (1, 3, 640, 640)  
Results saved to runs/detect/predict11  
💡 Learn more at https://docs.ultralytics.com/modes/predict  
(yolo) mjrovai@raspi-zero:~/Documents/YOLO $
```

YOLOv11 versus v8 - Inference

YOLOv8



YOLOv11



Other Computer Vision Tasks

YOLO Segmentation Result



YOLO Pose Estimation Result



Setting up Jupyter Notebook



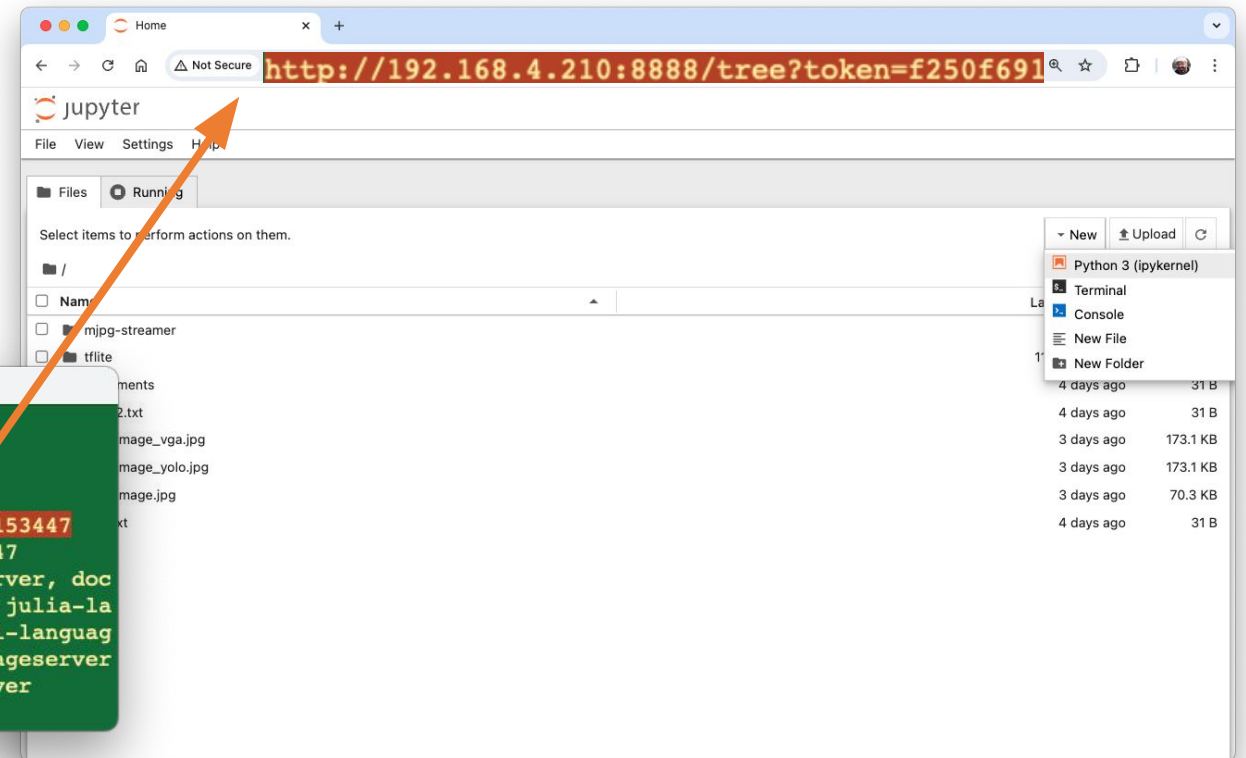
```
pip install jupyter jupyterlab notebook
```

```
jupyter notebook --ip=[YOUR IP ADDRESSES] --no-browser
```

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

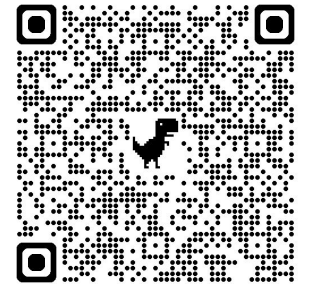
```
marcelo_rovai — mjrovai@raspi-zero: ~ — ssh mjrovai@192.168.4.210 — 96x12

To access the server, open this file in a browser:
  file:///home/mjrovai/.local/share/jupyter/runtime/jpserver-7399-open.html
Or copy and paste one of these URLs:
  http://192.168.4.210:8888/tree?token=f250f69117df5adf9d1aff01dd3ede657cb47b0ba8153447
  http://127.0.0.1:8888/tree?token=f250f69117df5adf9d1aff01dd3ede657cb47b0ba8153447
[I 2024-08-23 19:40:59.979 ServerApp] Skipped non-installed server(s): bash-language-server, doc
kerfile-language-server-nodejs, javascript-typescript-langserver, jedi-language-server, julia-la
nguage-server, pyright, python-language-server, python-lsp-server, r-languageserver, sql-languag
e-server, texlab, typescript-language-server, unified-language-server, vscode-css-languageserver
-bin, vscode-html-languageserver-bin, vscode-json-languageserver-bin, yaml-language-server
```



Raspberry Pi Inference:

YOLO Model Predictions with Ultralytics.ipynb



Questions?



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