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Make you IoT Smarter with Tensorflow Lite …

… to Design the Future of Vertical Farming

RTONE
IoT Makers

@alexis0duque

Who am I?

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- https://goo.gl/oNUWu6

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IoT makers

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TensorFlow Lite ?

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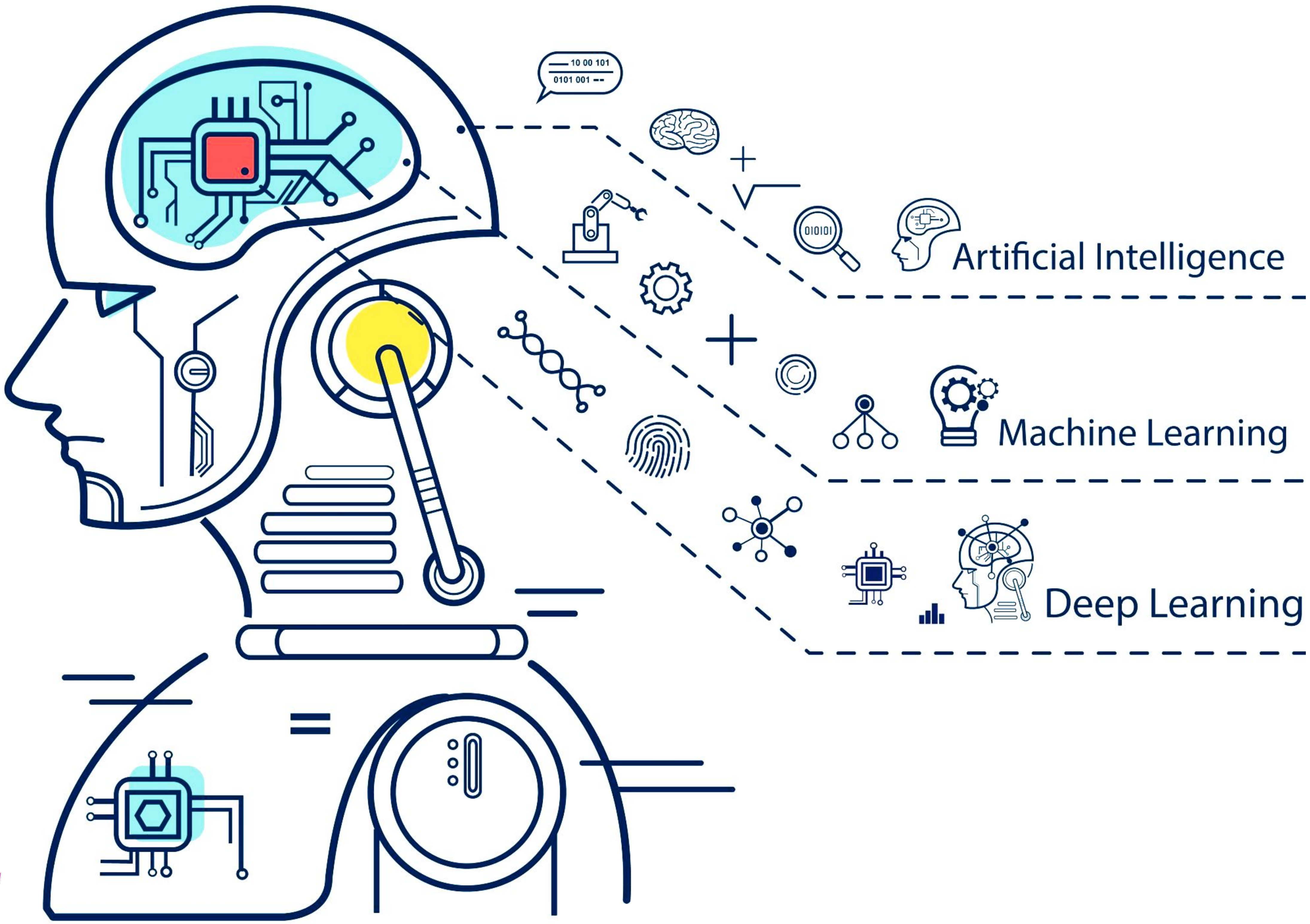

10 00 101
0101 001
Artificial Intelligence
Machine Learning
Deep Learning

?


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SUNBELT

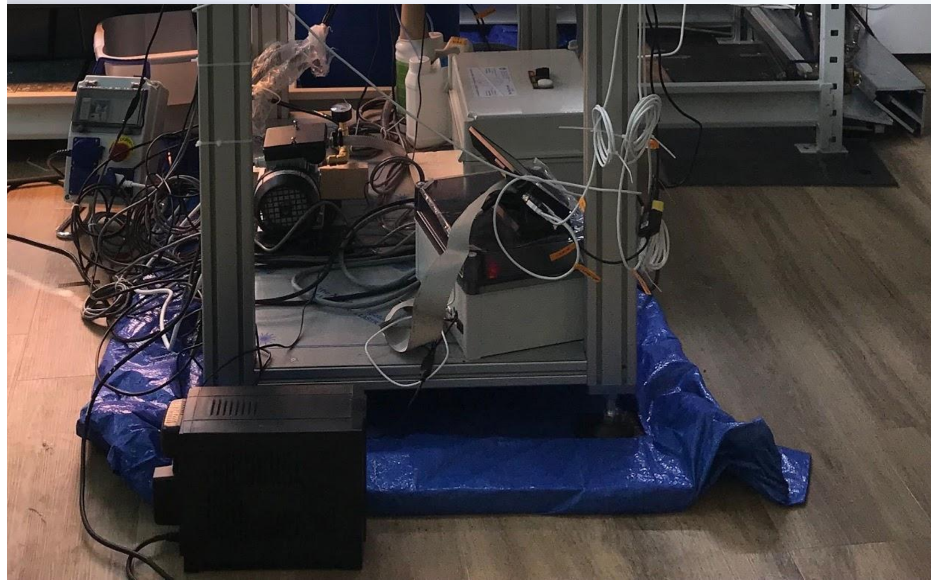
?

Outline & What You Will Learn

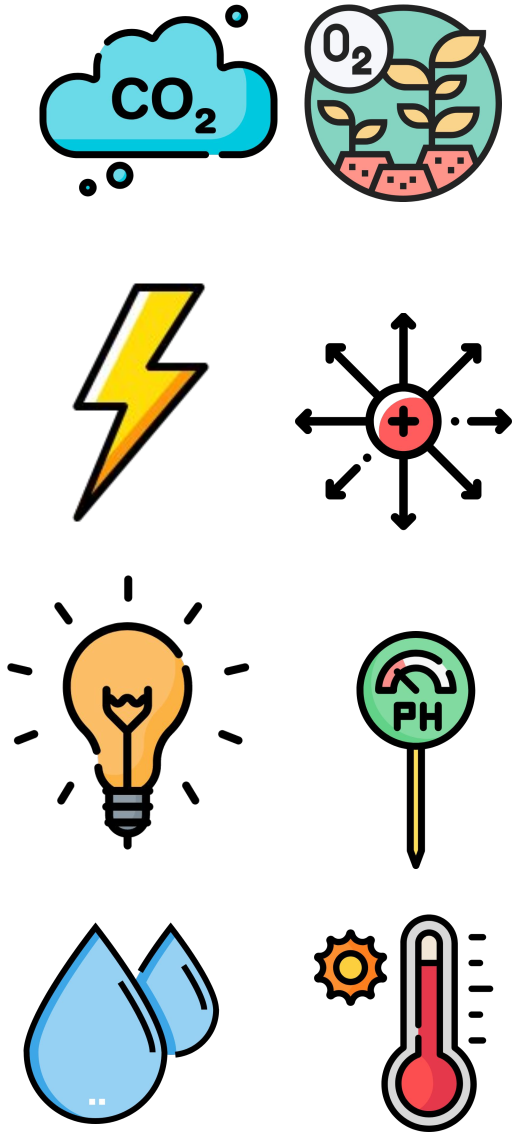
- **Indoor Vertical Farming**
- Why **Intelligence** at the **Edge**?
- Introduction to **Tensorflow Lite.** How to Use It?
- **Setup** your laptop & RPI
- **Build** and **train** a small model to **predict lettuce weight**
- **Convert** and deploy it on a RPI
- Run **predictions** on **IoT devices**
- Benchmarks
- Further Work

Indoor Vertical Farming

LA GRANGETTE



System Architecture



avg **co2** (double, in ppm)

avg **dissolved oxygen** (double, in ppm)

avg **electrical conductivity** (double, in µS/cm)

avg **RedOx potential** (double, in mV)

avg **PPFD** (Photosynthetic Photon Flux Density, double, in µmol/m2/s)

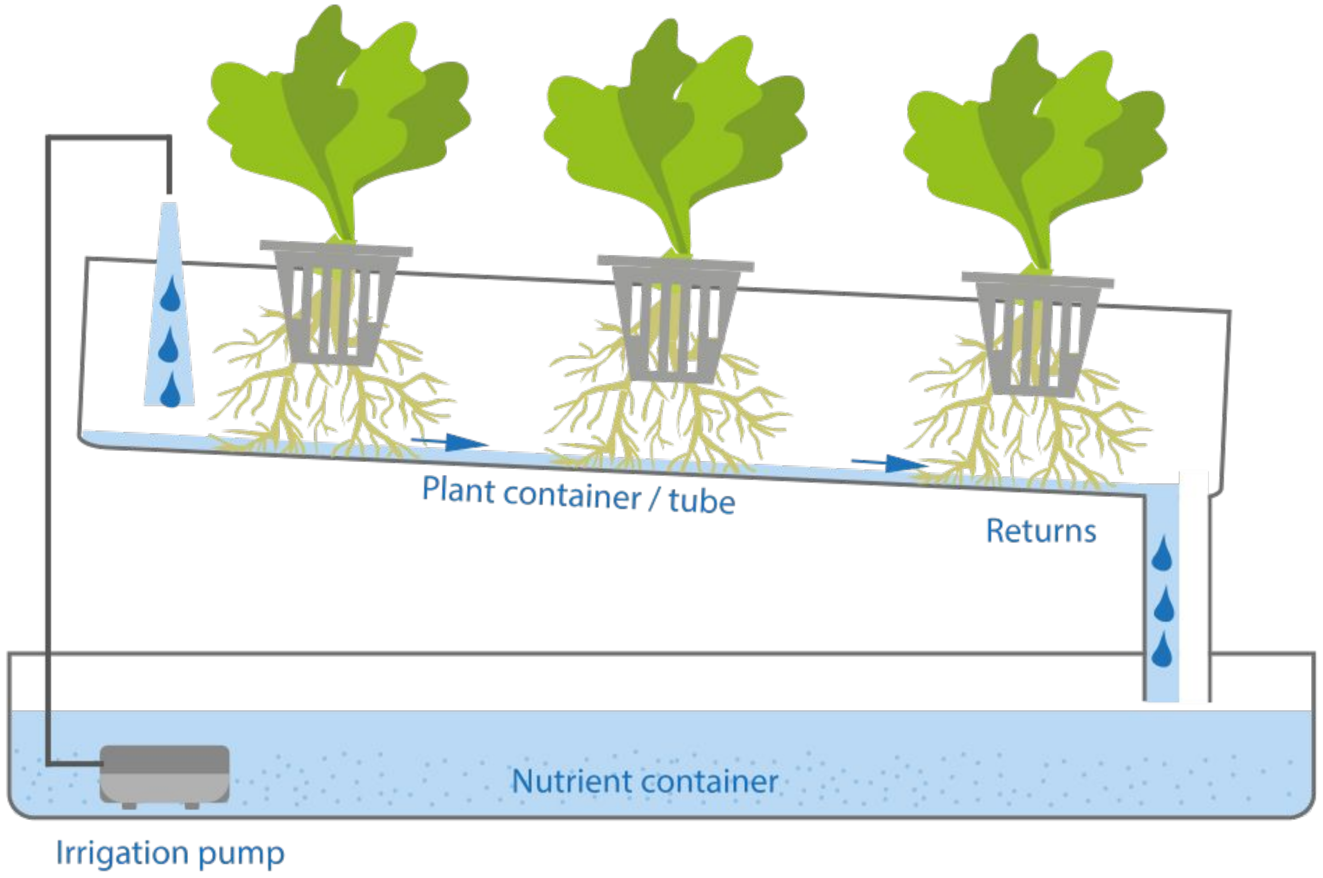
avg **water pH** (double, in -)

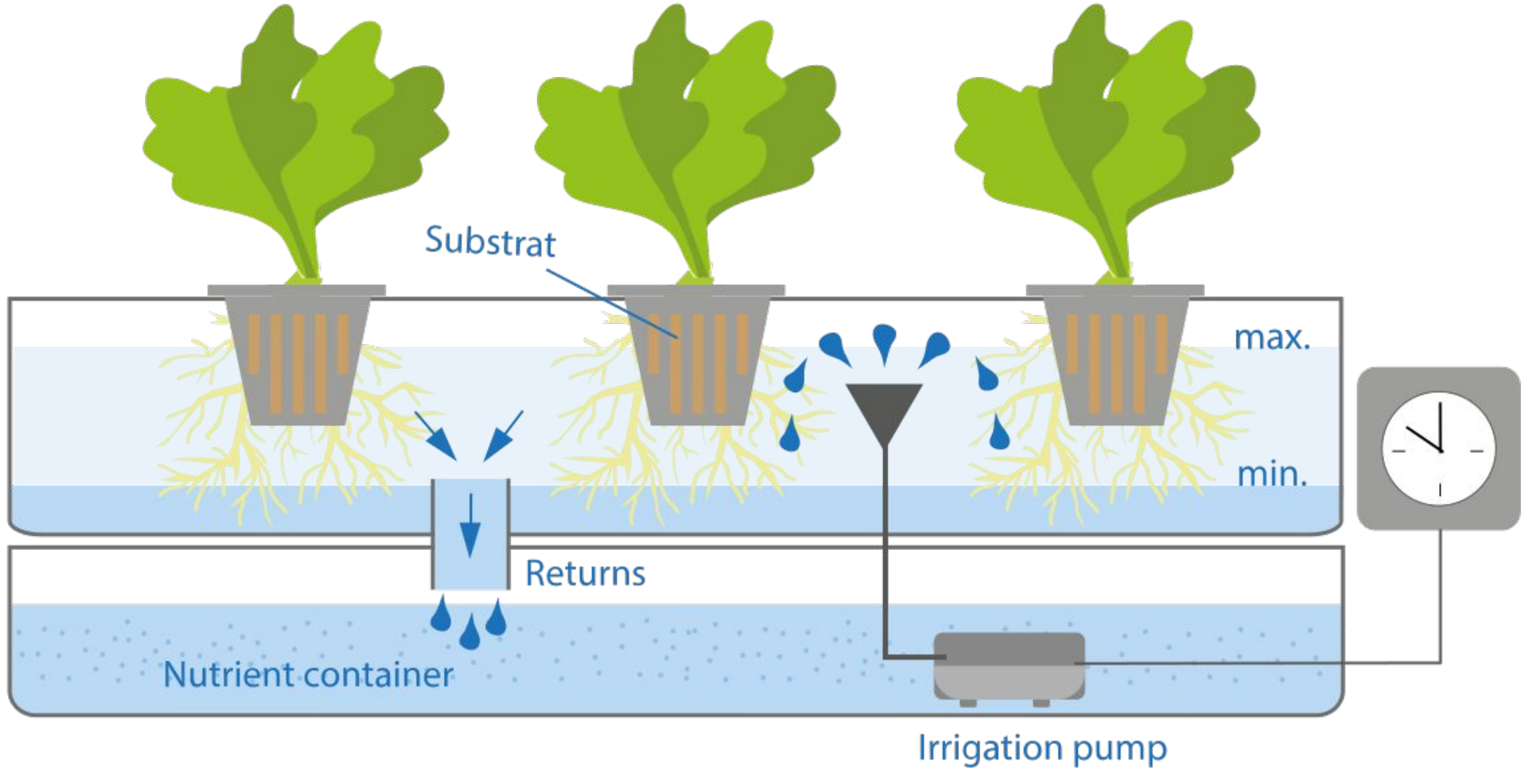
average **humidity** (double, in %)

average **temperature** (double, in °C)

Irrigation System

- HPA
- Nebulization
- NFT
- Ebb & Flow





https://www.hydroponic-urban-gardening.com/hydroponics-guide/various-hydroponics-systems

System Architecture

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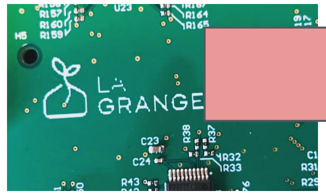
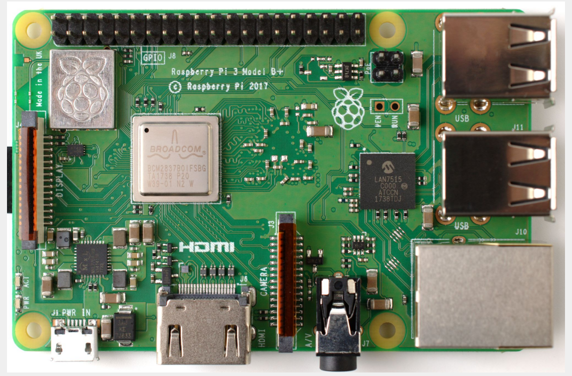
Sensors



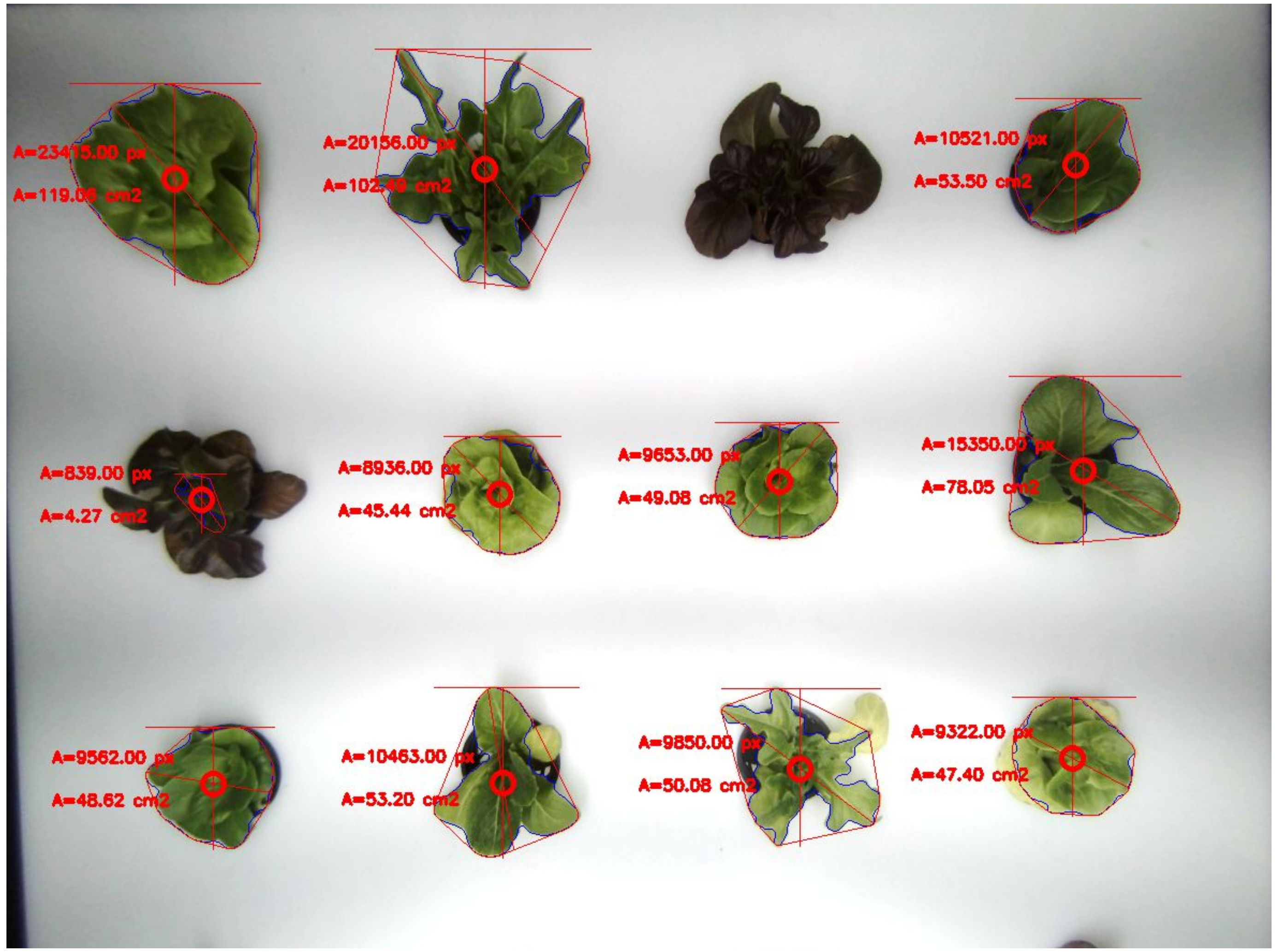
Motherboard

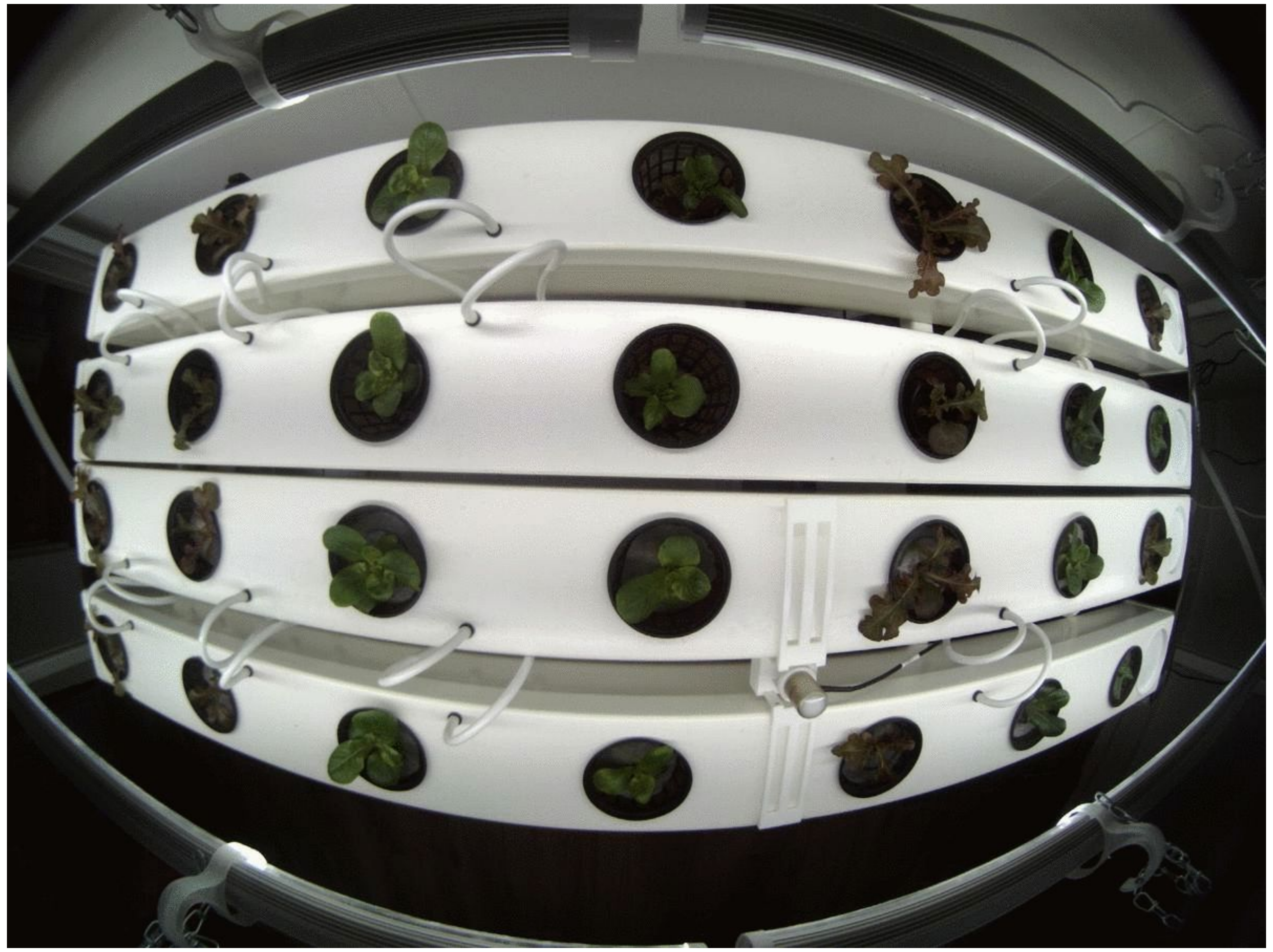


OpenCV

TensorFlow Lite

Computer Vision





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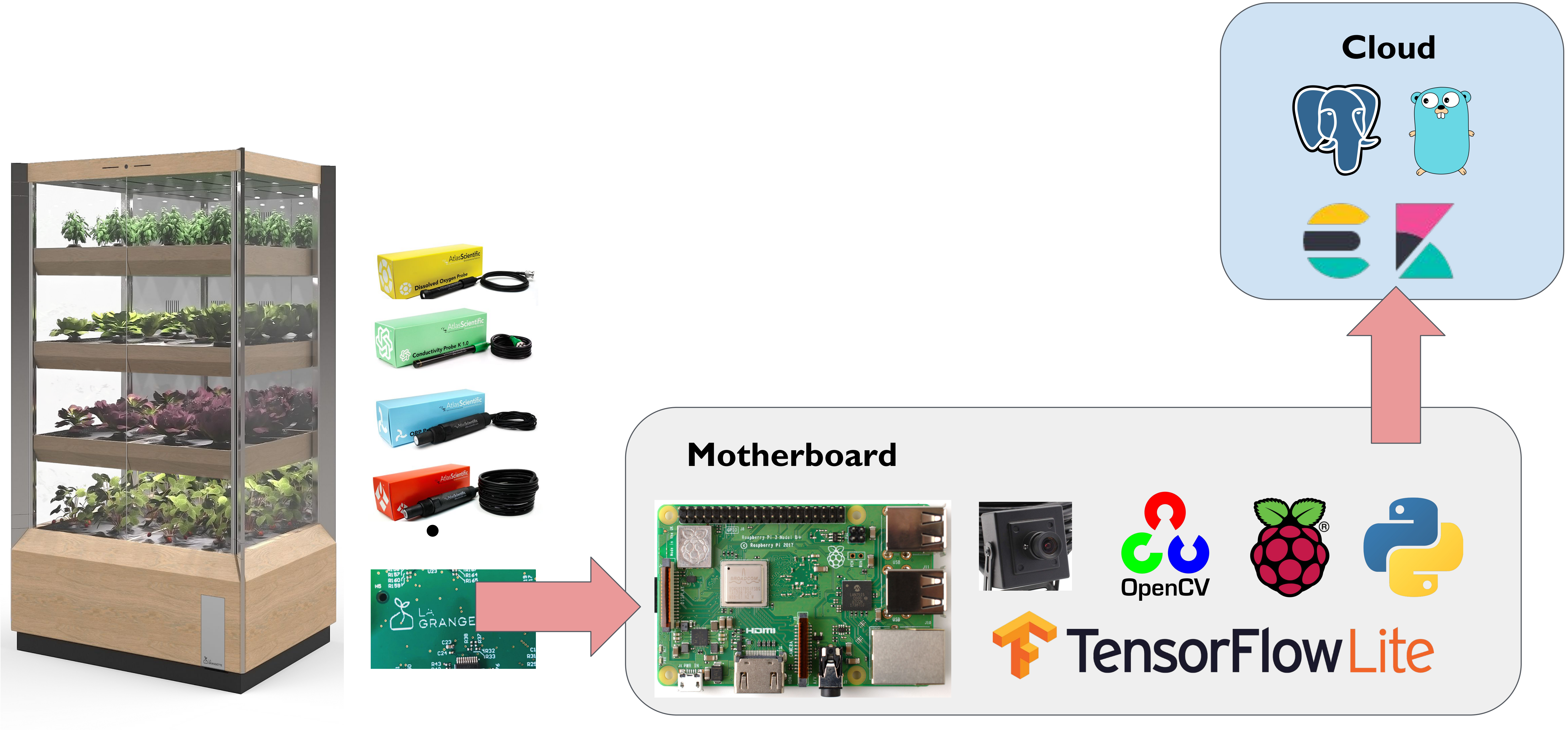

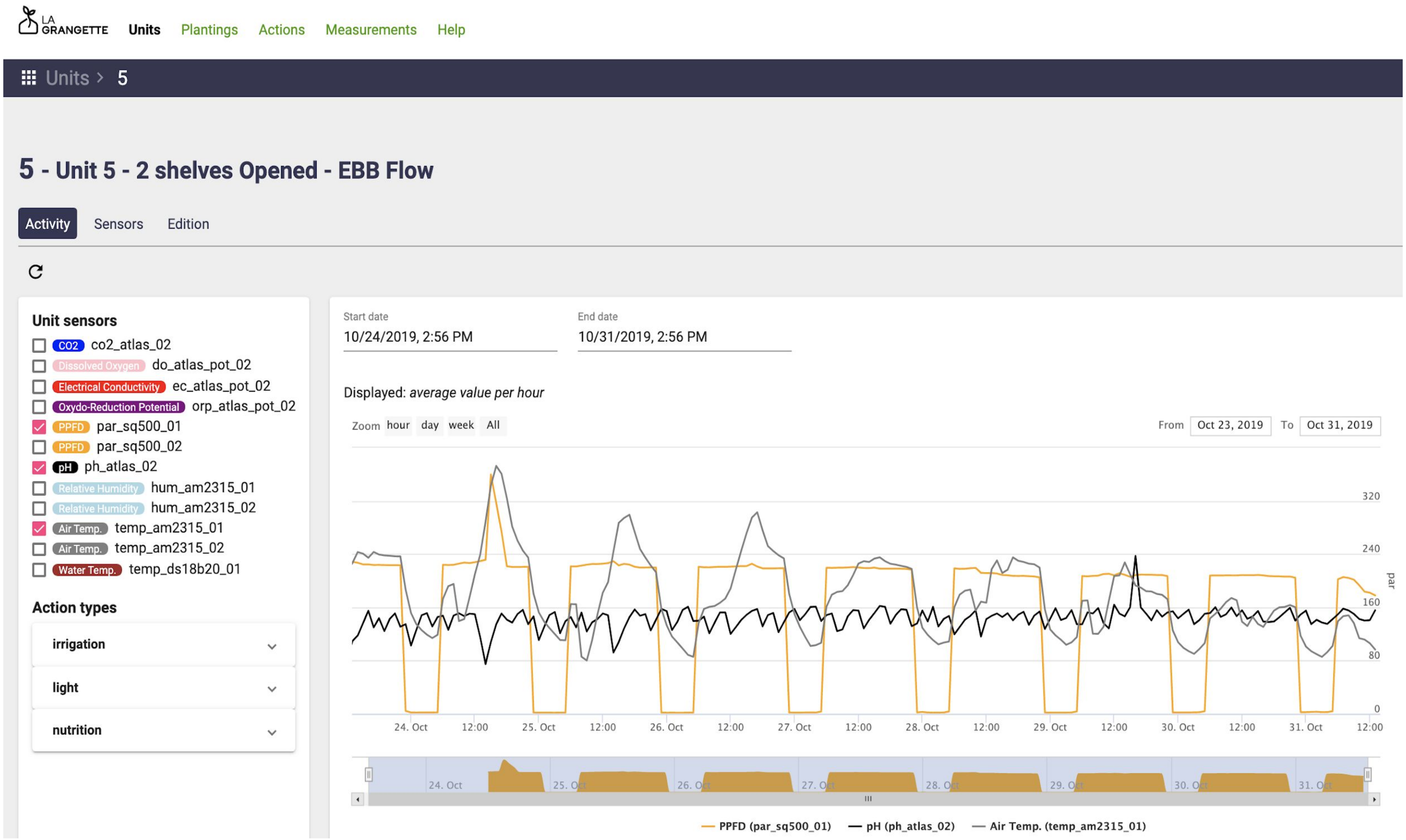

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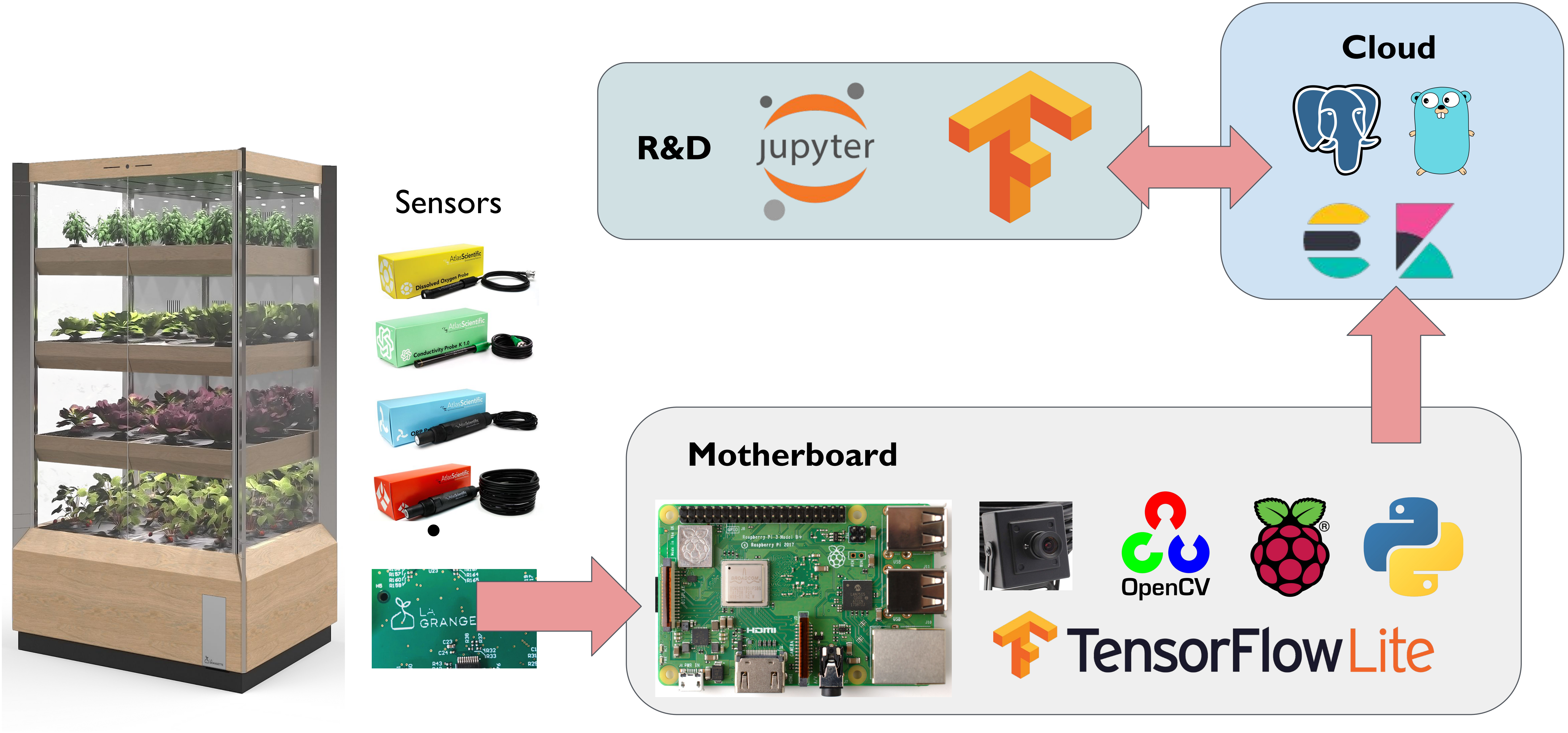
#FOSDEM #IoT #Tensorflow #AI

@alexis0duque

System Architecture



Why Machine Learning?

Is the system working as expected?

When my lettuce will be ready to be eaten?

What should I do to make vegetables looks and tastes better?

What should I do to make it grow faster?

[*Flavor-cyber-agriculture: Optimization of plant metabolites in an open-source control environment through surrogate modeling*]()

Johnson AJ, et al. (2019) Flavor-cyber-agriculture: Optimization of plant metabolites in an open-source control environment through surrogate modeling. PLOS ONE 14(4): e0213918.

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Why Edge Computing?

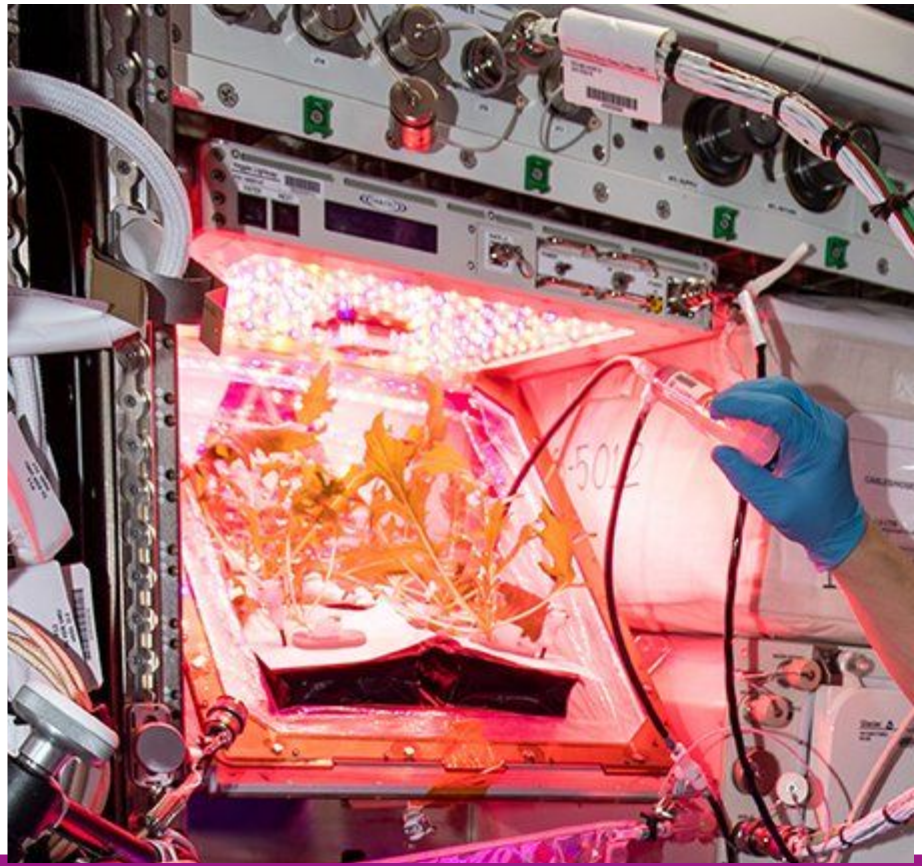
Infrastructure and cloud cost

Scalability

Must work in the field, without internet

Network Latency

Privacy



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Tensorflow

TensorFlow

Open source library created by Google

Platform for Machine Learning

2.0 (released on October 2019)

Create, train, debug and use various machine learning model (neural network but not only!)

Keras, Lite, Tensorboard, Tensorflow Probability

Tensorflow Lite (TF-Lite)

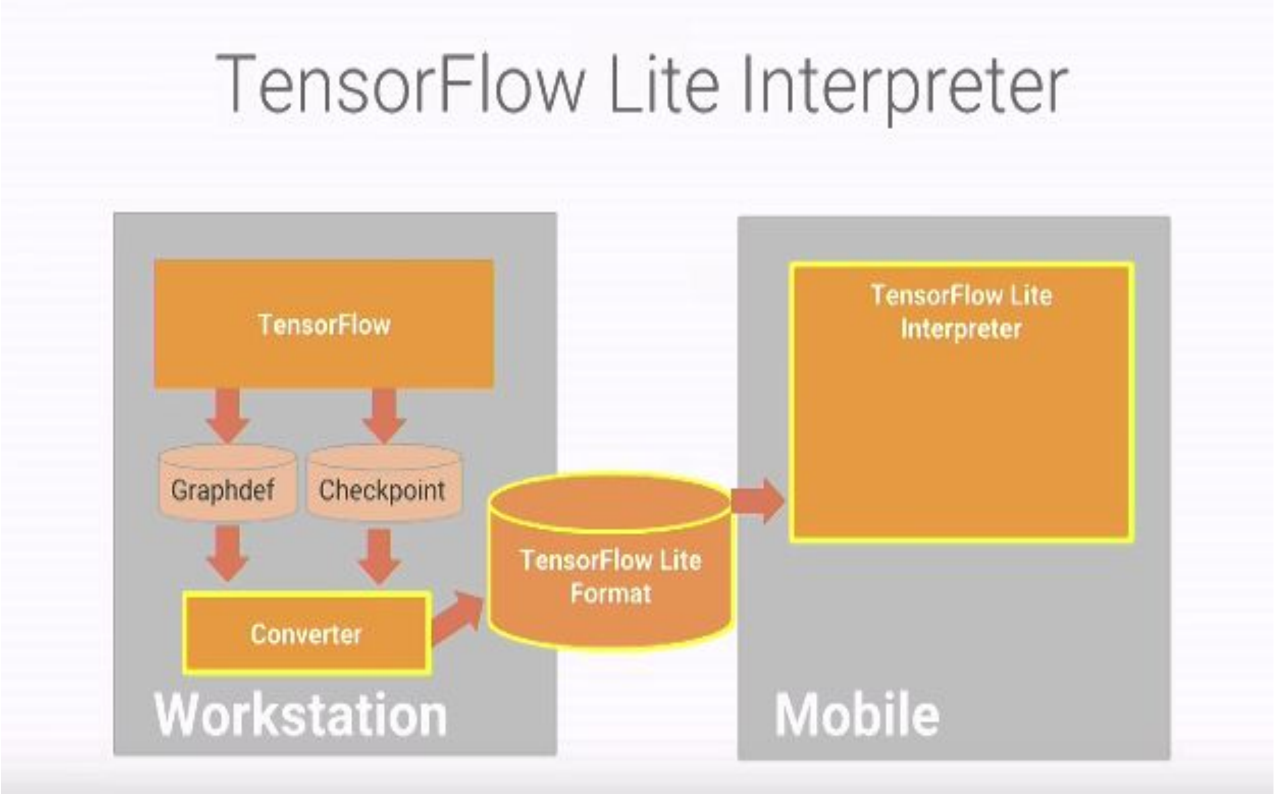
Converter + Interpreter

Tensorflow vs TF-Lite ?

- smaller model size
- faster inference
- mobile, embedded, MCU

but

- no training
- model is frozen => no re-training
- no transfer learning



Tensorflow Lite (TF-Lite)

TensorFlow Lite

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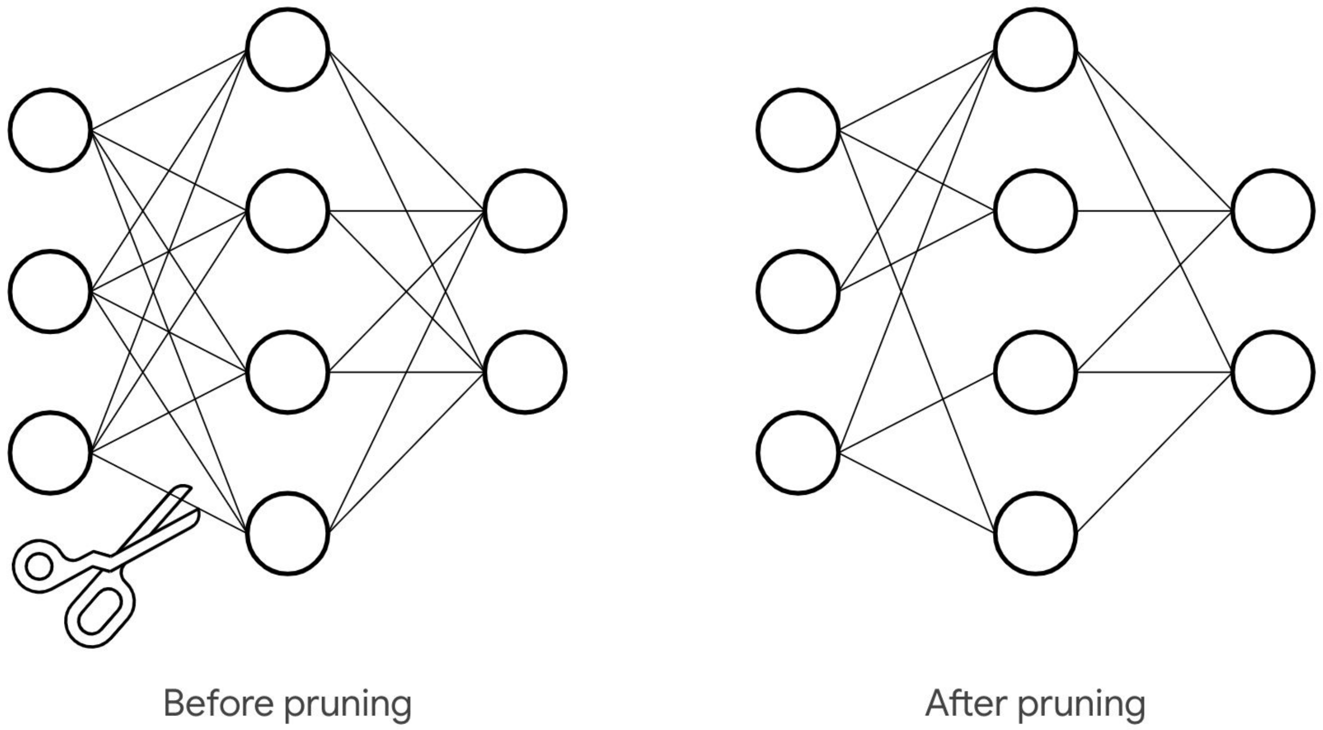
Optimization

- Pruning
- Post Training Quantization



Delegate to offload execution

- GPU, TPU, DSP

ML Workflow with Tensorflow Lite

Import your **dataset**

Work on data: preprocessing, normalization, features selection

Build your model with **Tensorflow**

Train your model

Export and **convert** to **.tflite**

ML Workflow with Tensorflow Lite

ARDUINO iOS android TensorFlow Lite

Load your model (*or grab one in* github.com/tensorflow/models)

Preprocess input data

Allocate Memory

Run inference

Interpret output

Setup on your Laptop

```
$ python3 --version
$ pip3 --version
$ virtualenv --version

$ virtualenv --system-site-packages -p python3 ./venv
$ source ./venv/bin/activate
$ pip install --upgrade pip
$ pip install --upgrade tensorflow=2.0
$ pip install numpy pandas jupyter jupyterlab notebook
matplotlib
```

Setup on your RPI

Tensorflow Lite Interpreter

1. Using pip and official TF release (not alway up to date)
2. Cross compile Tensorflow for ARMv7 on your laptop
3. Build Bazel and Tensorflow on your RPI (> 24h)
4. **Using pip and a *community built* .whl package**

https://github.com/PINTO0309/Tensorflowlite-bin

Setup on your RPI

Tensorflow Lite Interpreter

```
$ sudo apt install swig libjpeg-dev zlib1g-dev python3-dev
python3-numpy unzip
$ wget
https://github.com/PINTO0309/TensorflowLite-bin/raw/master/2
.0.0/tflite_runtime-2.0.0-cp37-cp37m-linux_armv7l.whl
$ pip install --upgrade
tflite_runtime-2.0.0-cp37-cp37m-linux_armv7l.whl
```

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Demo

💻 **Part 1** - Build, Train and Convert a simple Neural Network model to predict lettuce weight

Part 2 - Deploy your tflite model on RPI and run inference

Tensorflow Lite Limitations

Reinforcement Learning

Transfer Learning

Recurrent Neural Network (RNN) like LSTM

Operation Compatibility

https://www.tensorflow.org/lite/guide/ops_compatibility

https://github.com/tensorflow/tensorflow/blob/master/tensorflow/lite/experimental/examples/lstm/g3doc/README.md

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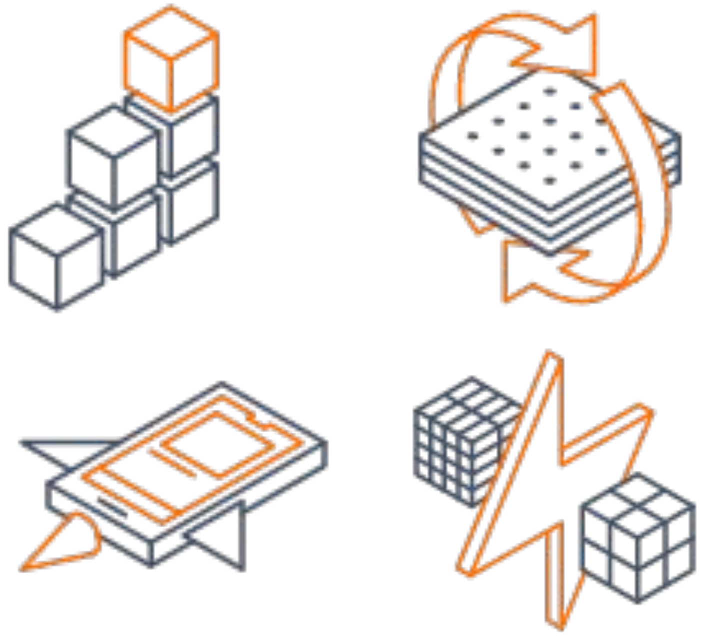
Further Work

Training at the Edge

Transfer Learning

Federated Learning

Summary



- Build, Train, Optimize, Convert on laptop
- Deploy, Infer on device
- Some operations are not supported
- Quantization does not affect accuracy
- Inference on IoT and microcontrollers is feasible
- Regression, anomalies detection, objects recognition, smart reply, etc.

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Thanks!

frama.link/rtone-jobs

frama.link/rtone-iot-tflite

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References

https://medium.com/tensorflow/how-to-get-started-with-machine-learning-on-arduino-7daf95b4157

https://www.tensorflow.org/lite

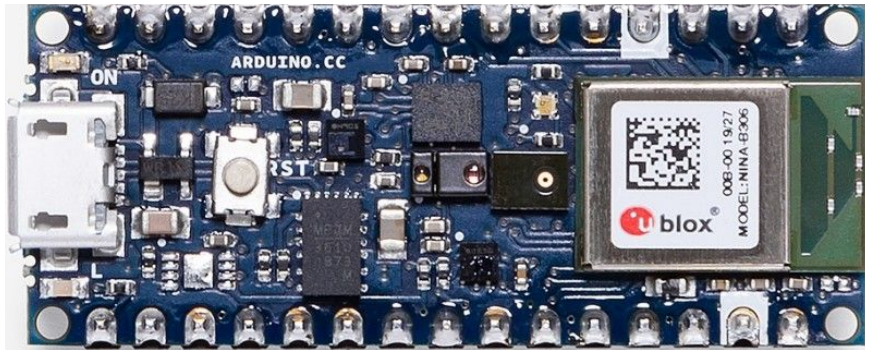
https://www.tensorflow.org

https://coral.withgoogle.com/

https://arxiv.org/abs/1902.01046

https://medium.com/tensorflow/tensorflow-model-optimization-toolkit-pruning-api-42cac9157a6a

TFLite on Microcontrollers



Arduino Nano 33

Inference on Cortex-M microcontroller

Only some operations are supported

Enough for hotword, gesture and speech recognition

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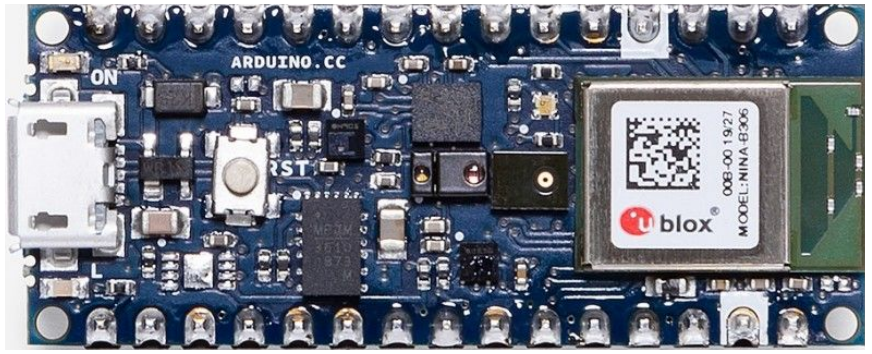
TFLite on Microcontrollers

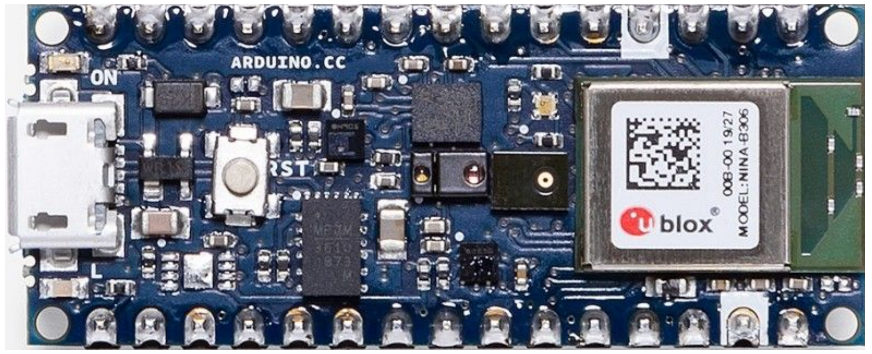


C++ API

```
#include <TensorFlowLite.h>
// This is your tflite model
#include "lg_weight_model.h"
#include
"tensorflow/lite/experimental/micro/kernels/all_ops_resolver.h"
#include "tensorflow/lite/experimental/micro/micro_interpreter.h"
#include "tensorflow/lite/schema/schema_generated.h"

tflite::ErrorReporter *error_reporter = nullptr;
const tflite::Model *model = nullptr;
tflite::MicroInterpreter *interpreter = nullptr;
TfLiteTensor *input = nullptr;
TfLiteTensor *output = nullptr;
```

TFLite on Microcontrollers

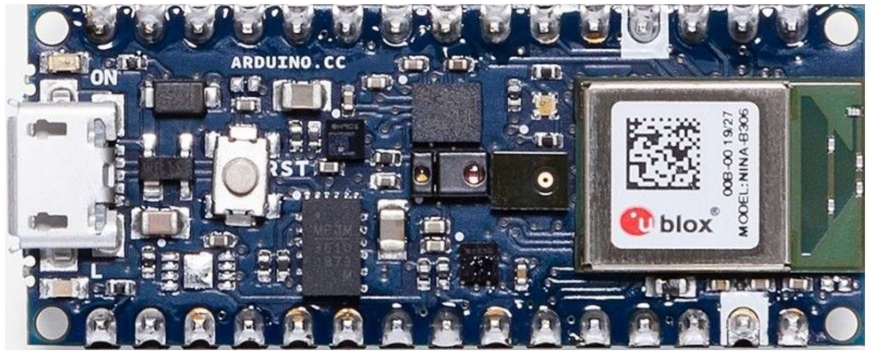



```
// Finding the min value for your model may require tests!
constexpr int kTensorArenaSize = 2 * 1024;
uint8_t tensor_arena[kTensorArenaSize];

// Load your model.
model = tflite::GetModel(g_weight_regresion_model_data);
// This pulls in all the operation implementations we need.
static tflite::ops::micro::AllOpsResolver resolver;

// Build an interpreter to run the model with.
static tflite::MicroInterpreter static_interpreter(
  model, resolver, tensor_arena, kTensorArenaSize, error_reporter);
interpreter = &static_interpreter;
```

TFLite on Microcontrollers




```
// Allocate memory for the model's tensors.
TfLiteStatus allocate_status = interpreter->AllocateTensors();
// Obtain pointers to the model's input and output tensors.
input = interpreter->input(0);
output = interpreter->output(0);
// Feed the interpreter with the input value
float x_val = random(0, 10);
input->data.f[0] = x_val;

// Run Inference
TfLiteStatus invoke_status = interpreter->Invoke();
// Get inference result
float y_val = output->data.f[0];
```