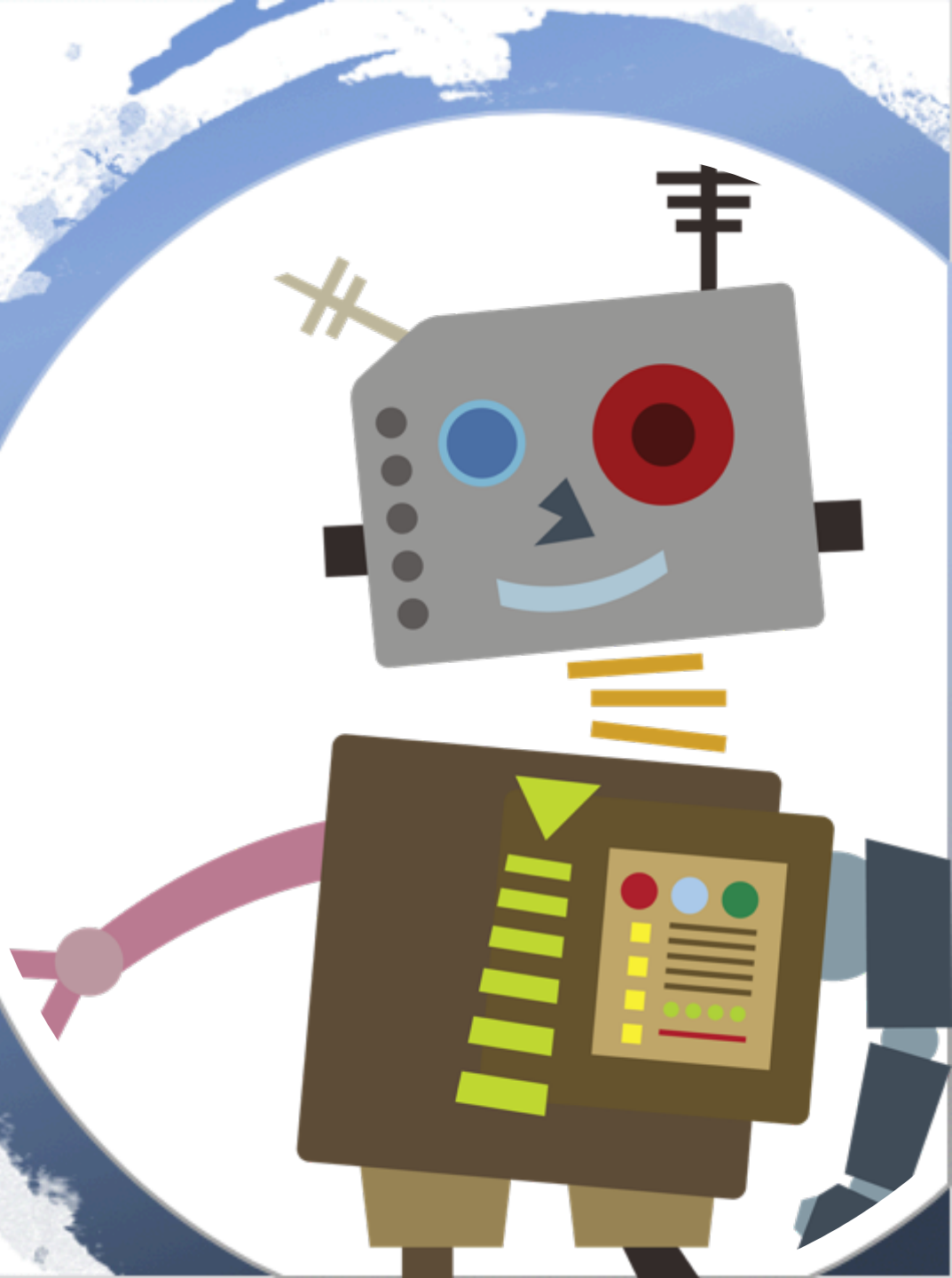
Exploring AI at the Edge!



By Marcelo Rovai

Meetup

IoT hacking & Data Science Innovators

August 27th, 2020

Marcelo Rovai

Brazilian from São Paulo, Master in Data Science by UDD, Chile, and MBA by IBMEC (INSPER), Brazil. Marcelo graduated in 1982 as an Engineer from UNIFEI with pos graduation by Poli/USP, both in Brazil. He worked as a teacher, engineer, and executive in several companies in the technology area such as AVIBRAS Aeroespacial, SID Informática, ATT-GIS, NCR, DELL, COMPAQ (HP) and more recently at IGT where he continues as Senior Advisor.

In 2016, Marcelo began writing about electronics, publishing his works in sites of the area as MJRoBot.org (Editor/Writer), Hackster.io (#1 Contributor), Instructables.com, and Medium.com (TDS – Towards Data Science). Besides winning several Instructables competitions in the areas of electronics, robotics, and IoT.

Marcelo lives with his wife Ilza in Santiago, Chile, where he divides his time between his consultant work and sharing ideas in the field of Data Science, Electronics, IoT, Physical Computing and Robotics.

Data → … → Value

Meetup

IoT hacking & Data Science Innovators

Data → ...→ Value

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Data (IoT) ➔ Value (AI)

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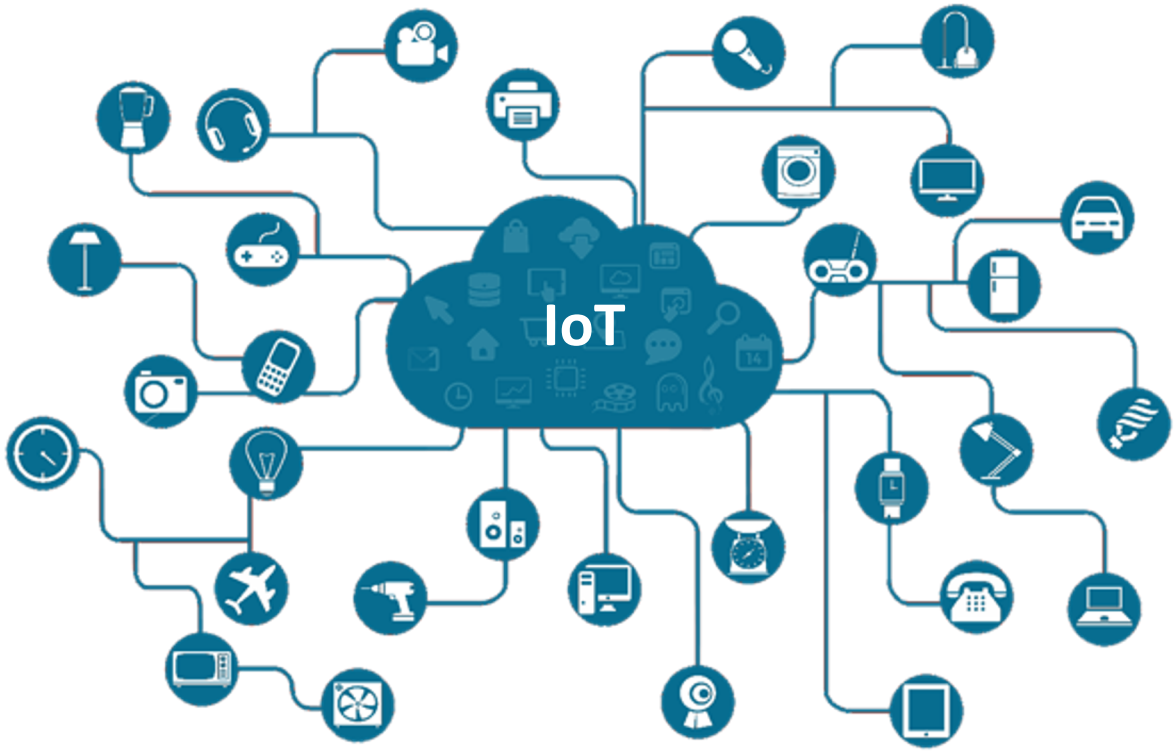

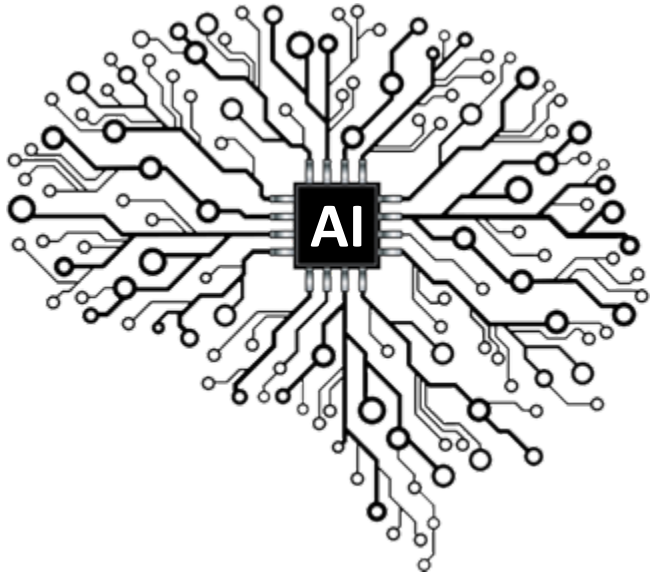

Data (IoT) ➔ Value (AI)

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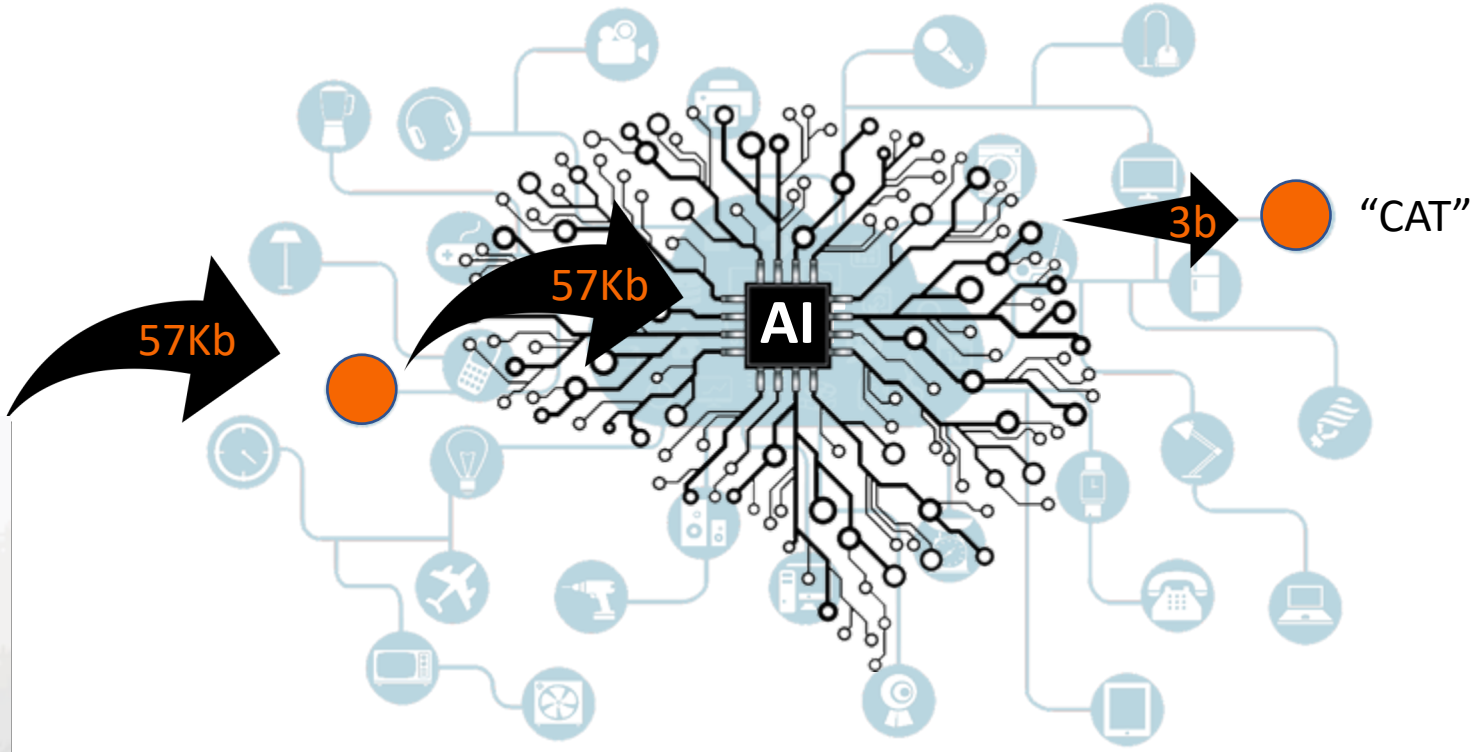

(146, 134, 3) ➔ 146 ∗ 134 ∗ 3 = 57,486 pixels

1 pixel ➔ 0 to 255 (1 byte)

AI at the Edge ➔ Edge AI

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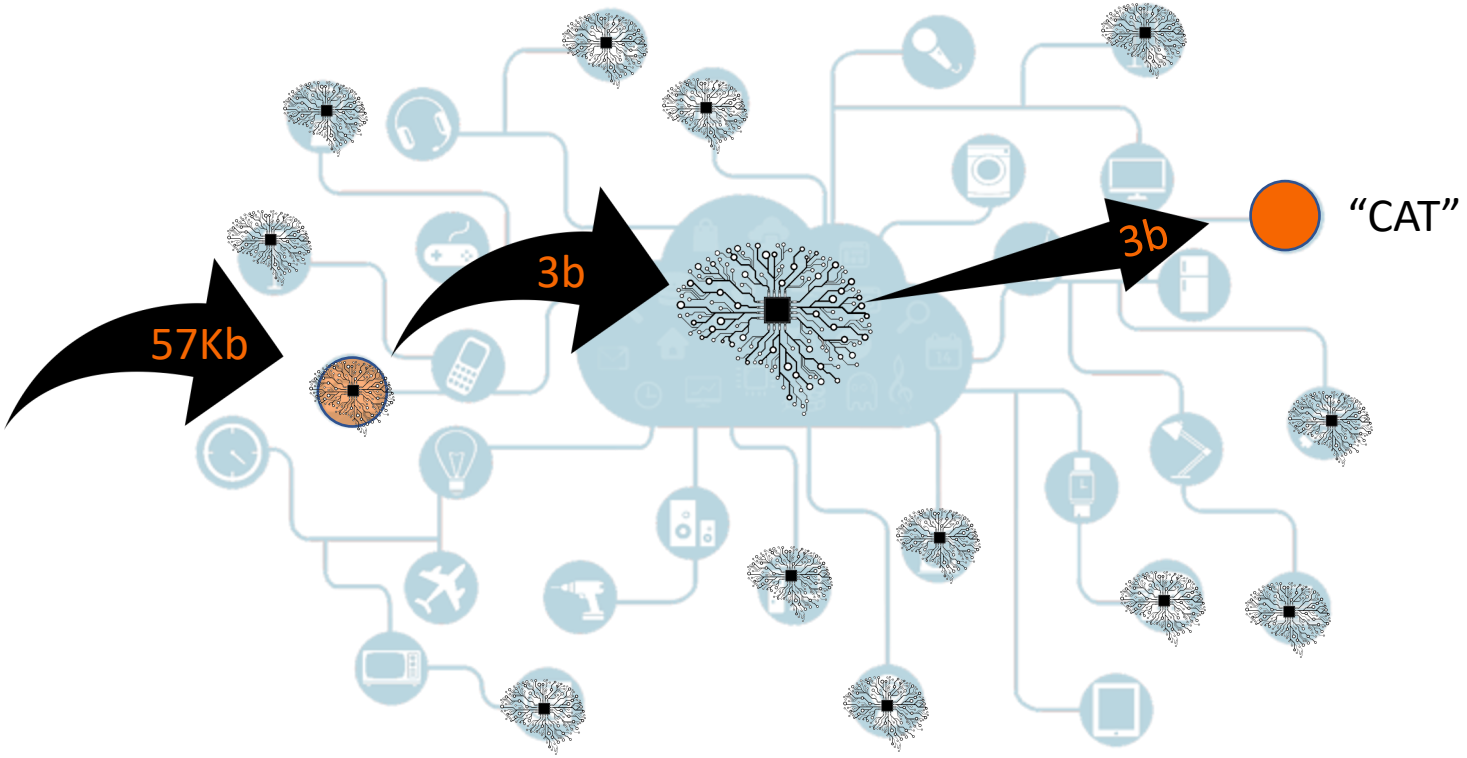

"The term "Edge AI" might be the new buzzword of 2019/2020, much like "Internet of Things" was in 2016/2017. "

https://www.digikey.com/en/maker/projects/what-is-edge-ai-machine-learning-iot/4f655838138941138aaad62c170827af

AI → Deep Learning (DL)

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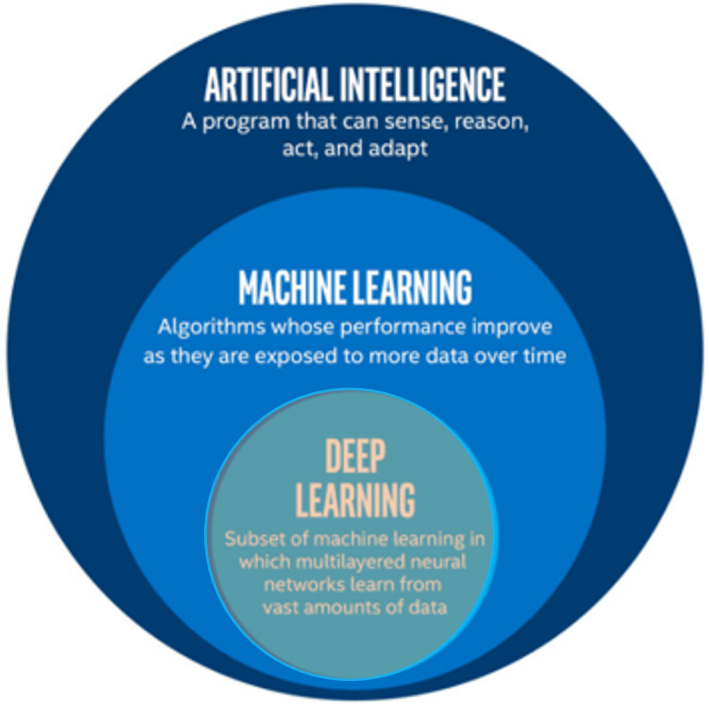
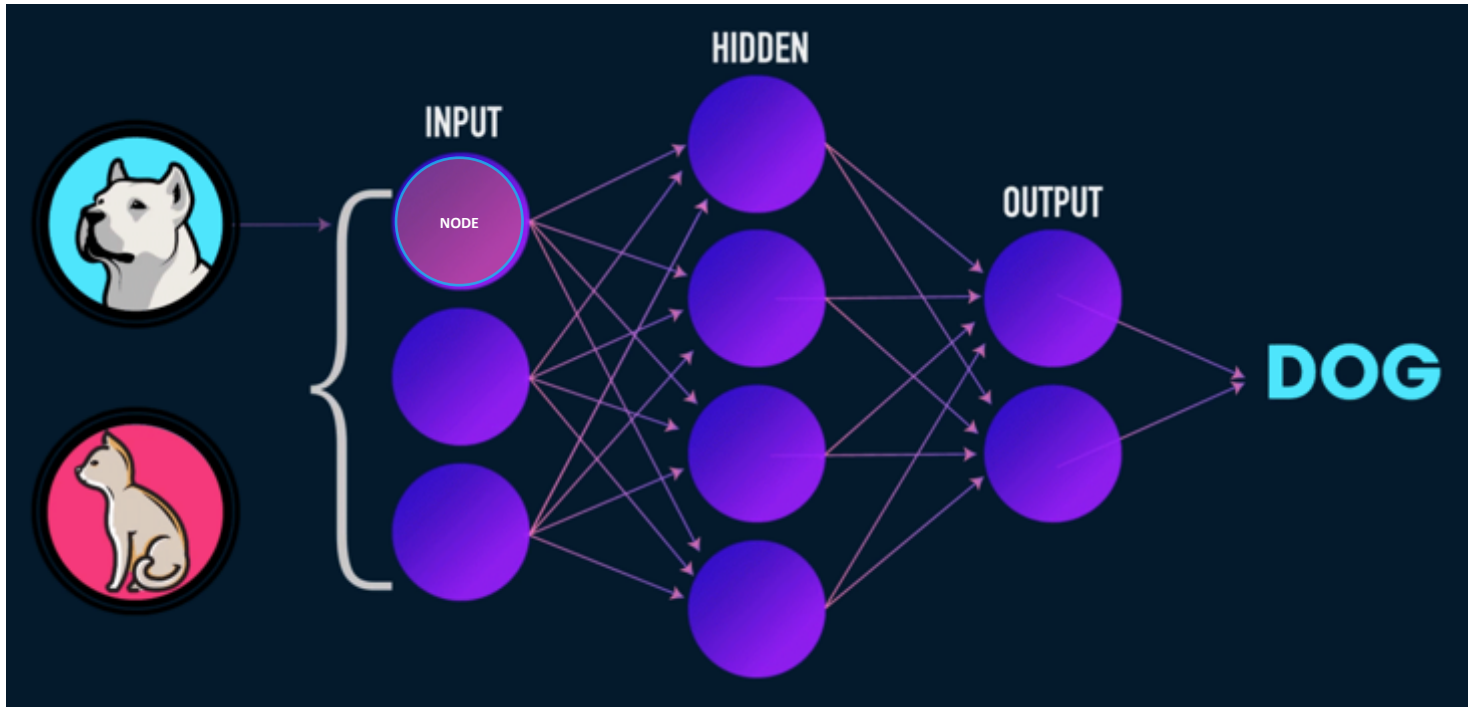
Deep Learning: Subset of Machine Learning in which multilayered neural networks learn from vast amounts of data





Source Image: https://towardsdatascience.com/an-introduction-to-deep-learning-af63448c122c

Neuron

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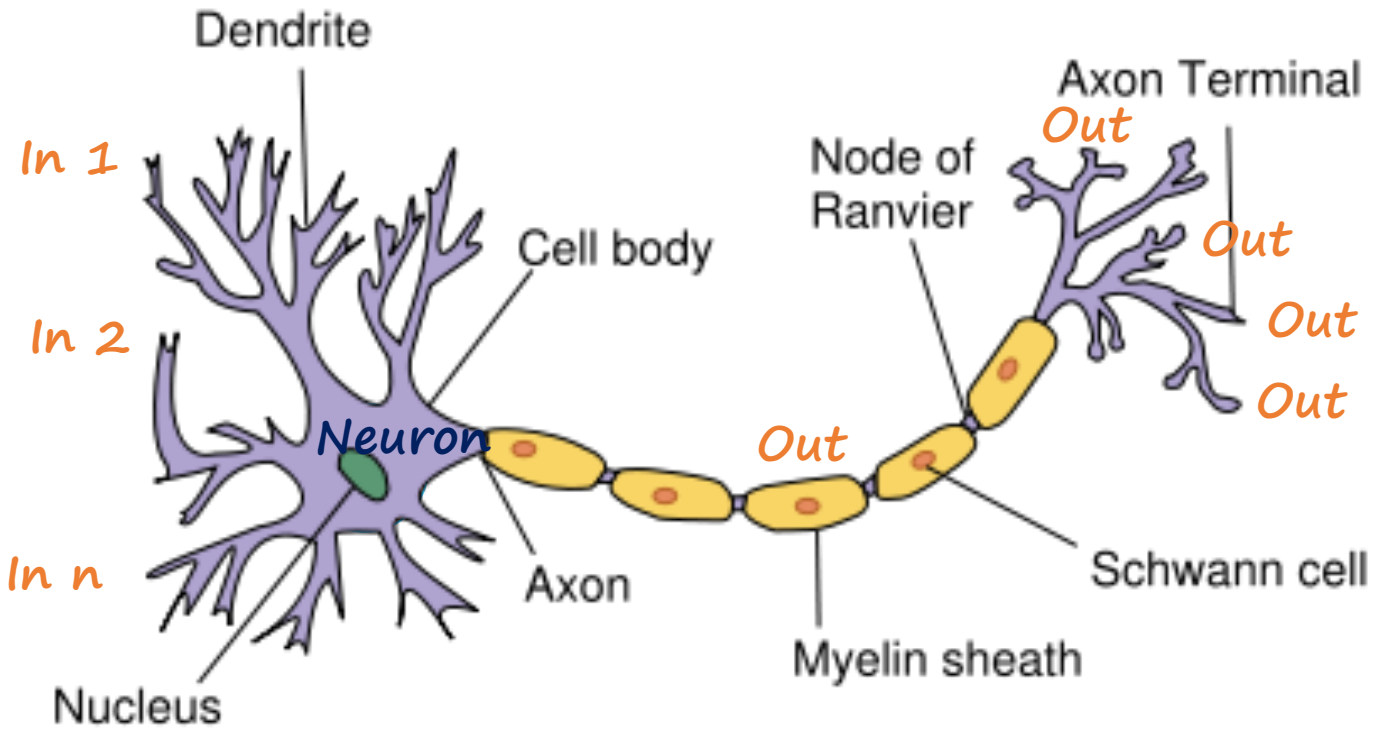

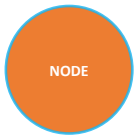

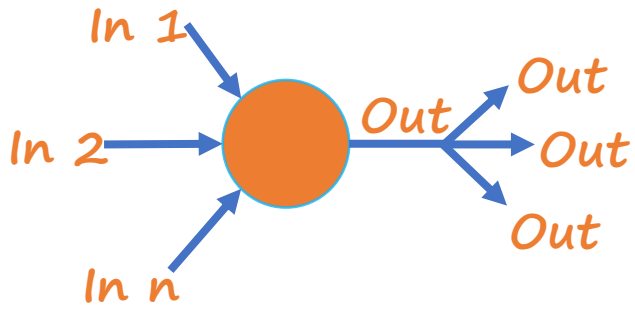

Artificial Neural Network

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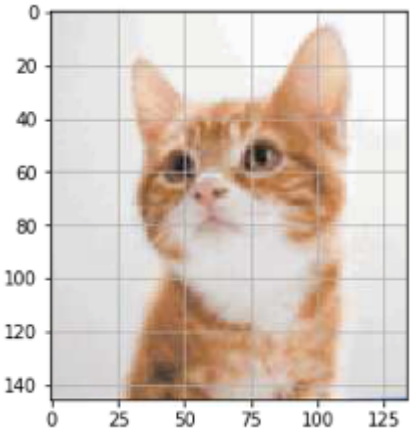
IoT hacking & Data



(146, 134, 3)

RGB

```
[[227, 228, 227, ..., 249, 249, 249],
 [219, 219, 219, ..., 249, 249, 249],
 [221, 221, 221, ..., 249, 249, 249],
 ...,
 [209, 209, 209, ..., 220, 220, 218],
 [209, 209, 209, ..., 205, 205, 204],
 [208, 209, 209, ..., 124, 119, 121]]
```

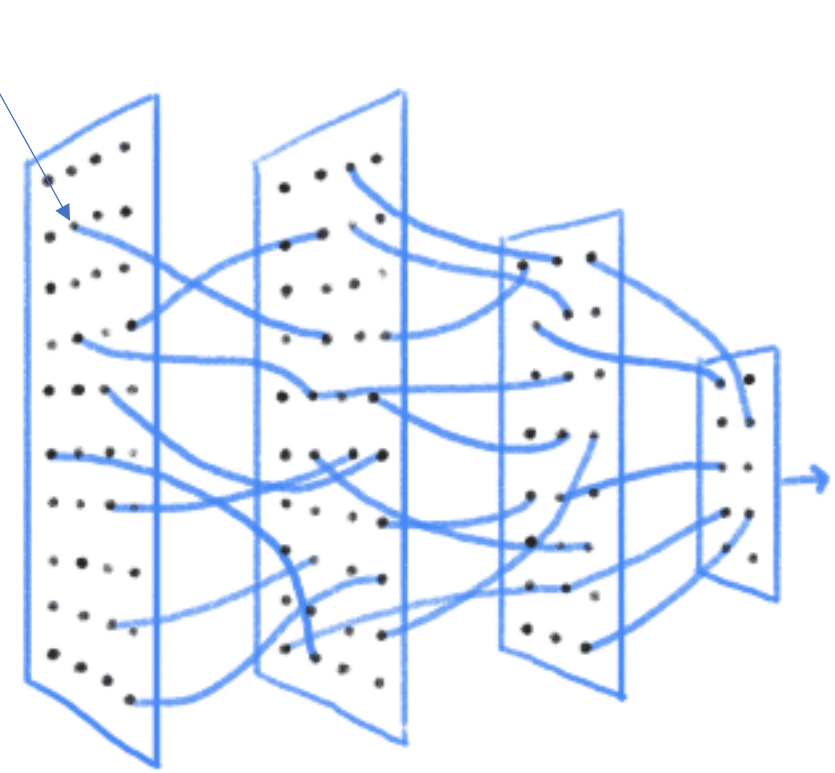
146 * 134 * 3 = 57,486 pixels

[227, 228, 227... 124, 119, 121]

CAT

(LABELED PHOTOS)

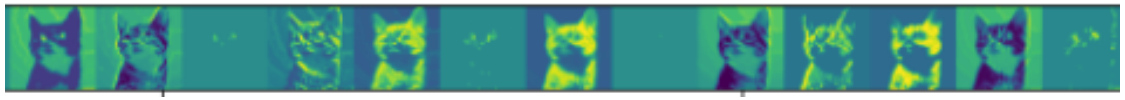
DOG



OUTPUT

cat

CNN (Layer 1) ➔



The Neural Network Zoo

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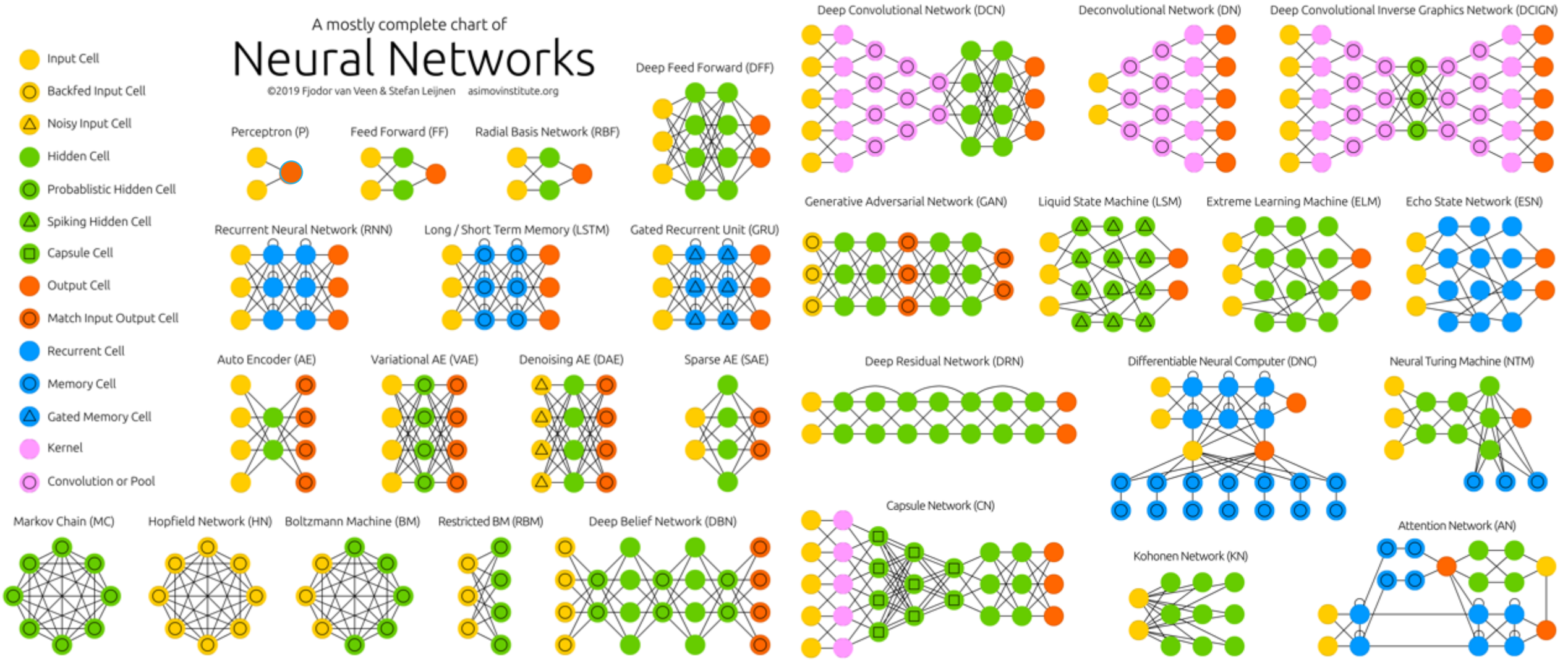

https://www.asimovinstitute.org/neural-network-zoo/

The Neural Network Zoo

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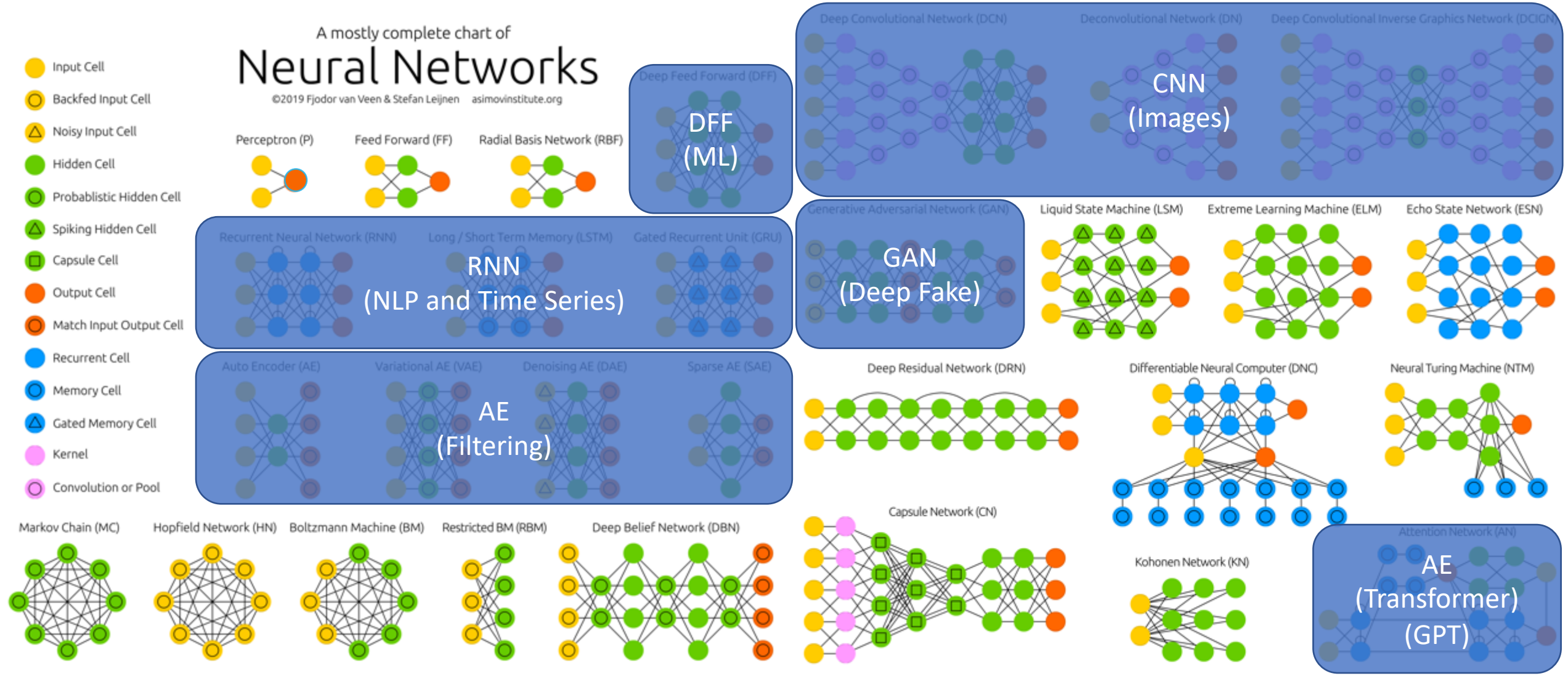

https://www.asimovinstitute.org/neural-network-zoo/

AI → Edge Computing

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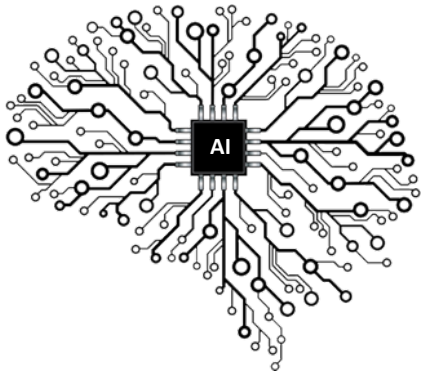
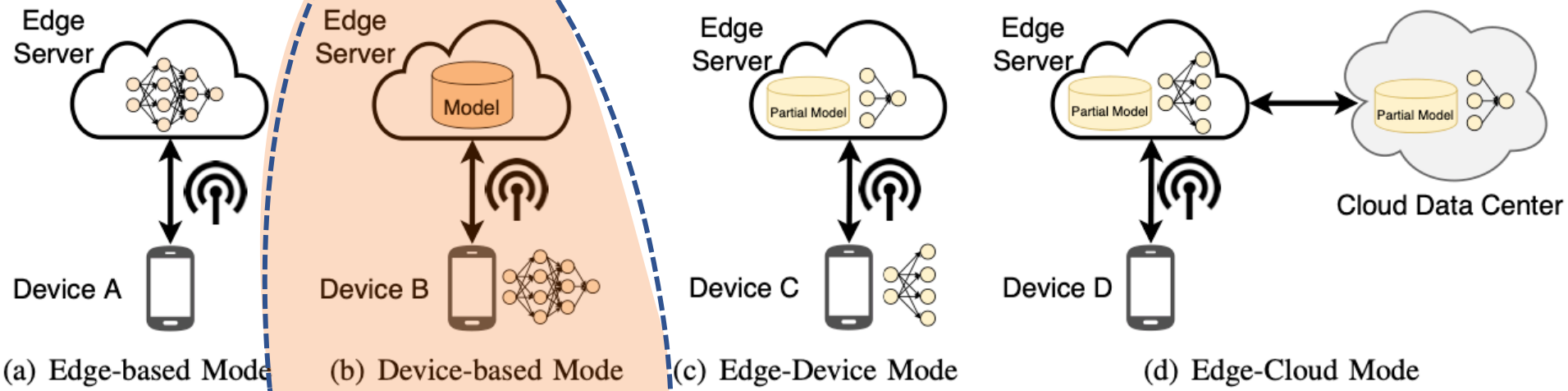
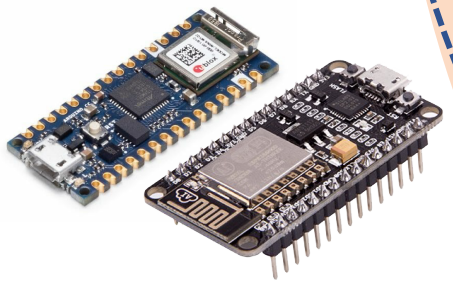




(a) Edge-based Mode (b) Device-based Mode (c) Edge-Device Mode (d) Edge-Cloud Mode

https://arxiv.org/pdf/1905.10083.pdf

Smart Phones



MCU (Nano 33IOT / ESP32)

RaspBerry Pi

BeagleBone

NVIDIA Jetson

Training vs. Inference

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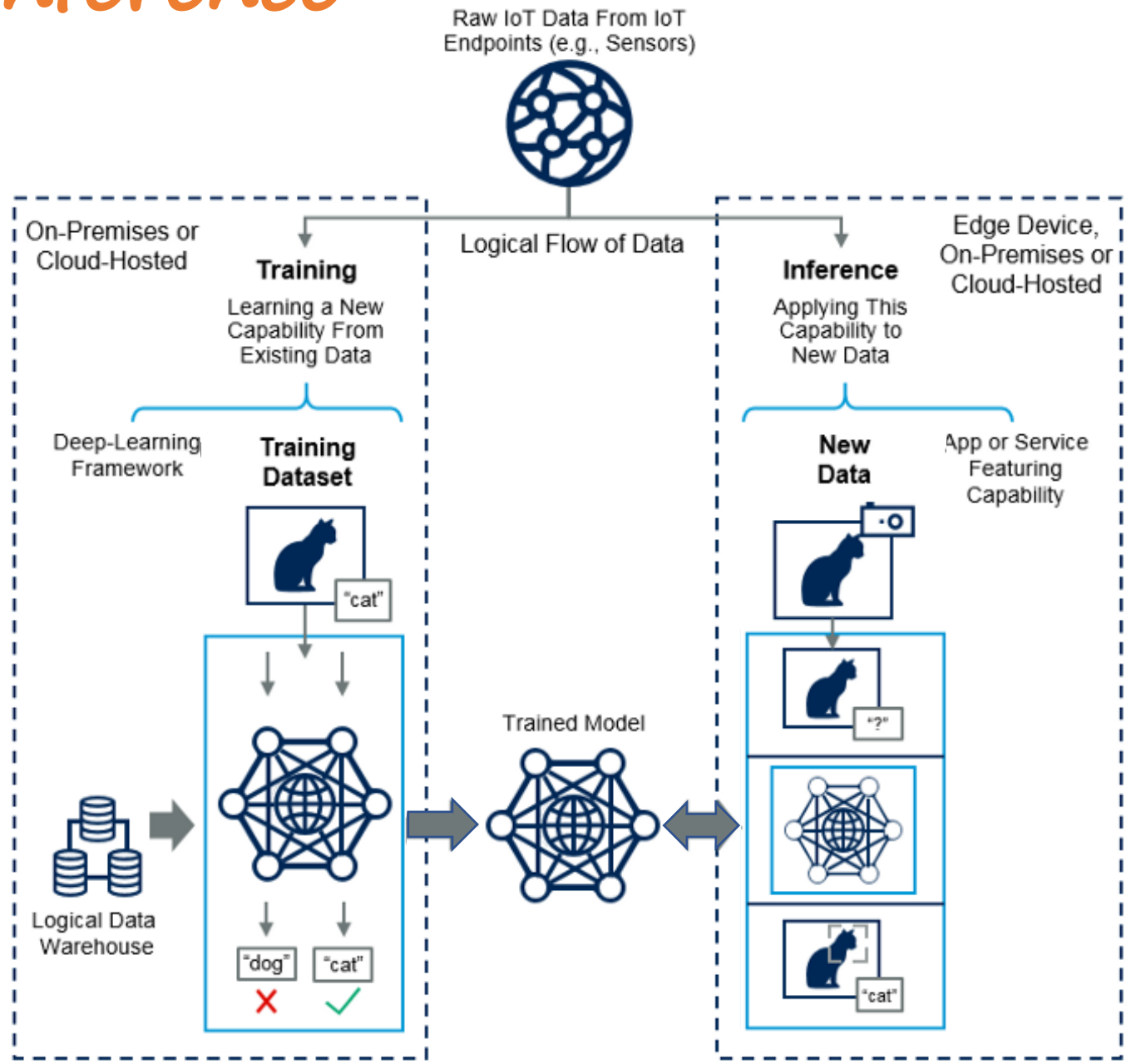

https://blogs.gartner.com/paul-debeasi/2019/02/14/training-versus-inference/

TensorFlow Lite

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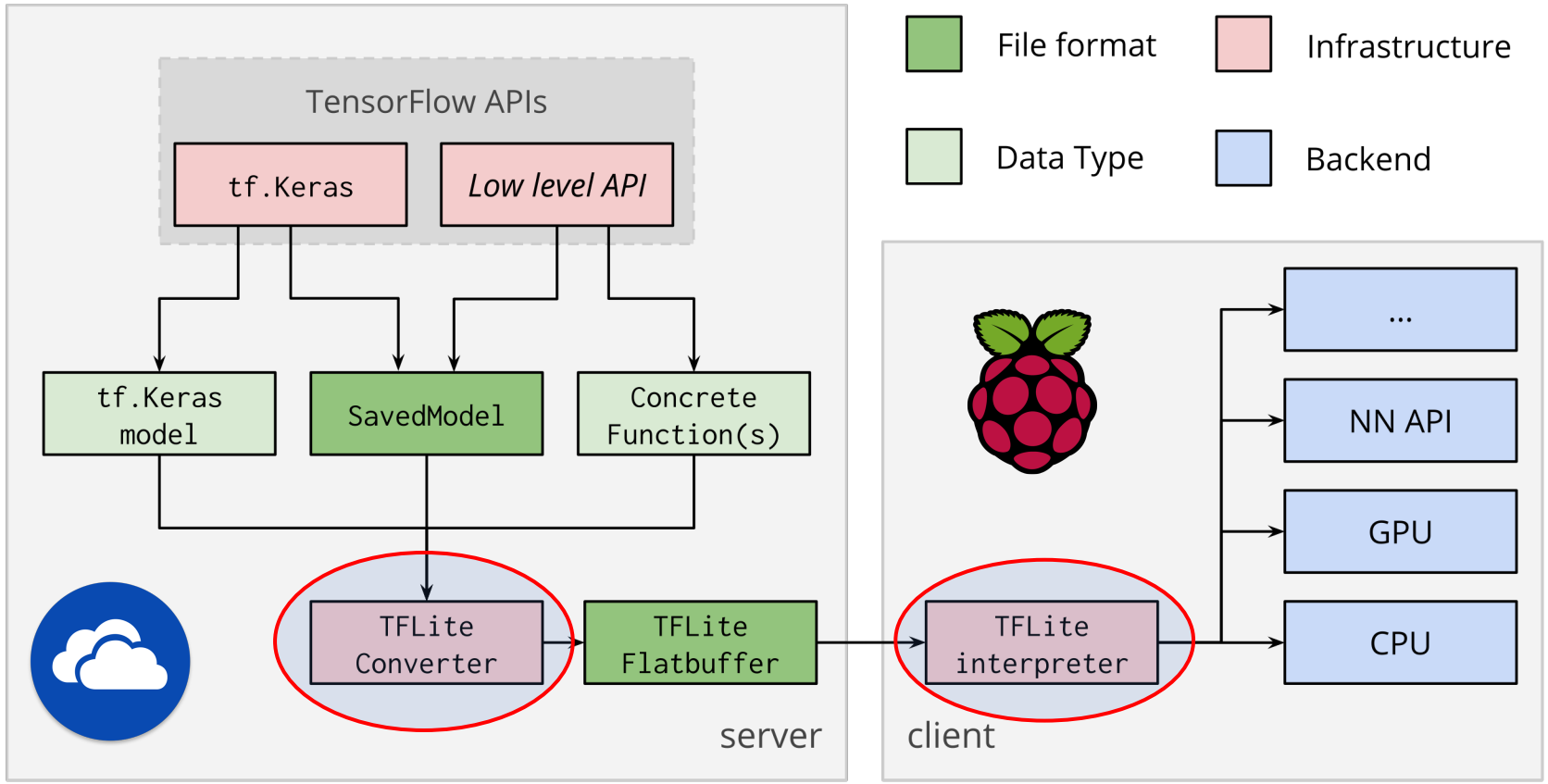

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Image Classification & Object Detection Live DEMO

Deep Learning Workflow

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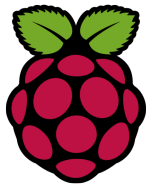
Decide a Goal → Collect a dataset → Design a model architecture

On-Premises / Cloud (Server)

Train a model → Convert a model

Edge Device (Client)



Run Inference → Evaluate and Troubleshoot

Demo 1 - Image Classification

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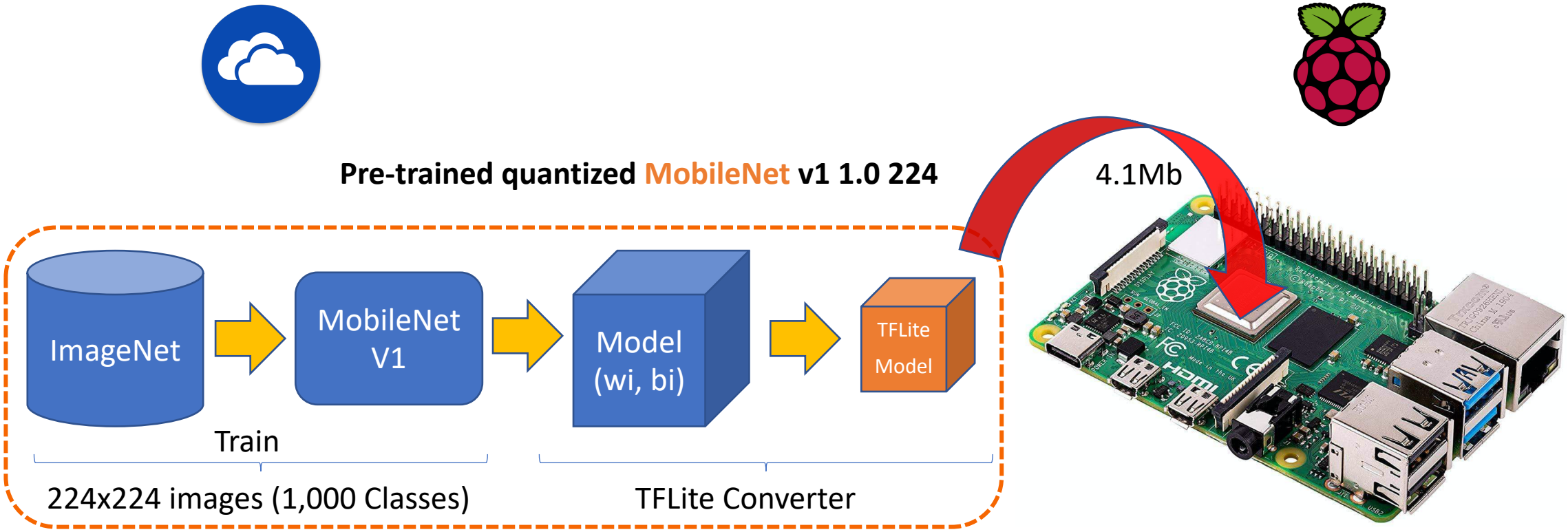

TF Lite Inference – Image Classification

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```
In [5]:  1  input_details

Out[5]: [{'name': 'input',
          'index': 88,
          'shape': array([  1, 224, 224,   3]),
          'dtype': numpy.uint8,
          'quantization': (0.0078125, 128),
          'quantization_parameters': {'scales': array([0.0078125], dtype=float32),
           'zero_points': array([128]),
           'quantized_dimension': 0}}]
```

Input Image Shape

```
In [6]:  1  output_details

Out[6]: [{'name': 'MobilenetV1/Predictions/Reshape_1',
          'index': 87,
          'shape': array([   1, 1001]),
          'dtype': numpy.uint8,
          'quantization': (0.00390625, 0),
          'quantization_parameters': {'scales': array([0.00390625], dtype=float32),
           'zero_points': array([0]),
           'quantized_dimension': 0}}]
```

Output model

TF Lite Inference – Image Classification

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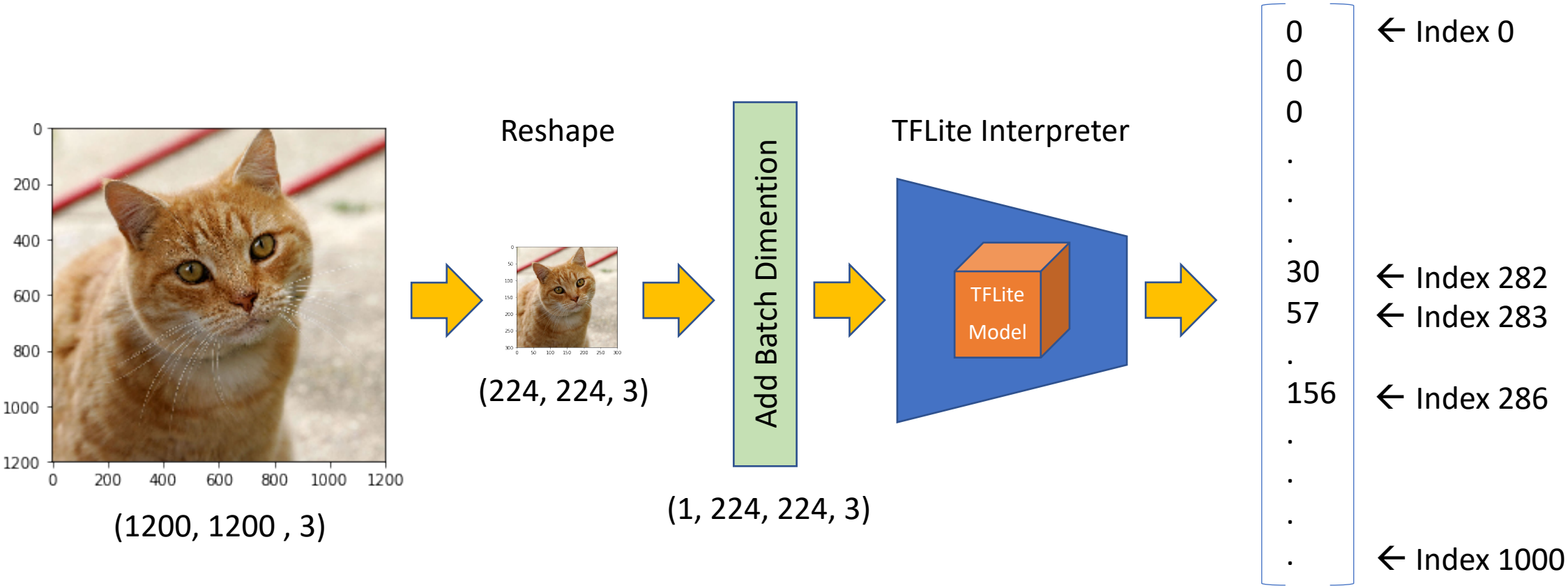

TF Lite Inference – Demo - Results

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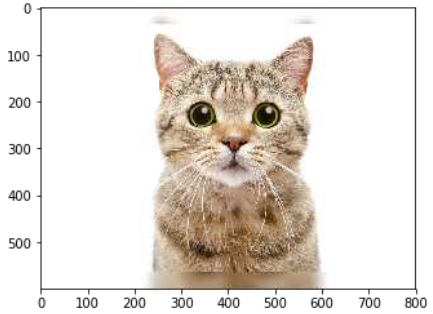
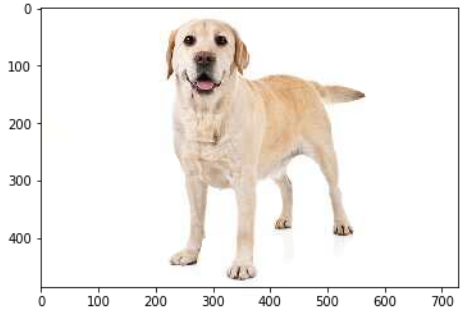
```
image_path = './images/cat_1.jpg'
image_classification(image_path, labels)
```

```
[PREDICTION]        [Prob]

Egyptian cat        : 64%
tabby               : 14%
bucket              : 3%
```



```
image_path = './images/dog_1.jpg'
image_classification(image_path, labels)
```

```
[PREDICTION]        [Prob]

Labrador retriever  : 83%
golden retriever    : 13%
bloodhound          : 0%
```



```
image_path = './images/pi_1.jpeg'
image_classification(image_path, labels)
```

```
[PREDICTION]        [Prob]

German shepherd     : 60%
dhole               : 16%
malinois            : 7%
```

```
image_path = './images/car_2.jpg'
image_classification(image_path, labels)
```

```
[PREDICTION]        [Prob]

minivan             : 76%
convertible         : 6%
jeep                : 4%
```

```
image_path = './images/ship_1.jpg'
image_classification(image_path, labels)
```

```
[PREDICTION]        [Prob]

liner               : 85%
trimaran            : 11%
aircraft carrier    : 0%
```

```
image_path = './images/table.jpg'
image_classification(image_path, labels)
```

```
[PREDICTION]        [Prob]

dining table        : 40%
table lamp          : 34%
desk                : 17%
```

Demo 2 - Object Detection

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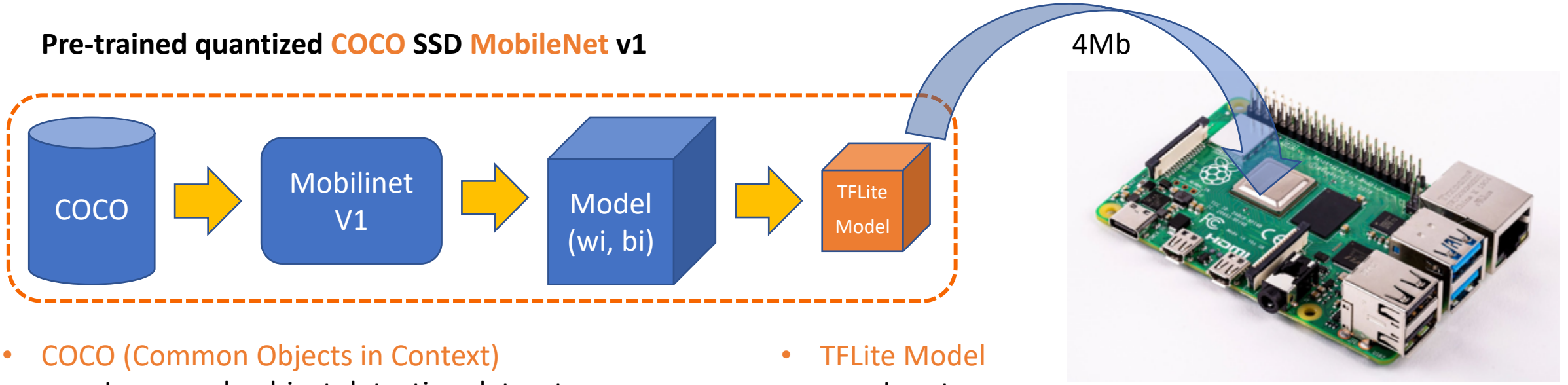
Pre-trained quantized COCO SSD MobileNet v1



- COCO (Common Objects in Context)
  - Large-scale object detection dataset
  - 200K labeled images
  - 91 Stuff categories
- MobileNet
  - “Depth- wise Separable” convolutions
  - Introduced by Google in 2017
  - Similar performance with state-of-the-art architectures (as VGG or Inception)
  - Much smaller network (20% of VGG parameters (7M)
- TFLite Model
  - Input:
    - Image: 300x300x3
    - Flattened Buffer: 270K bytes
    - Each byte: 0 to 255
  - Output:
    - Bounding Box ➔ (ymin, xmin, ymax, xmax)
    - Class ID (0 to 89) ("Stuff categories")
    - Score (0 to 1)

COCO Paper: https://arxiv.org/pdf/1405.0312.pdf

MobileNet paper: https://arxiv.org/pdf/1704.04861.pdf

TF Lite Inference - Object Detection

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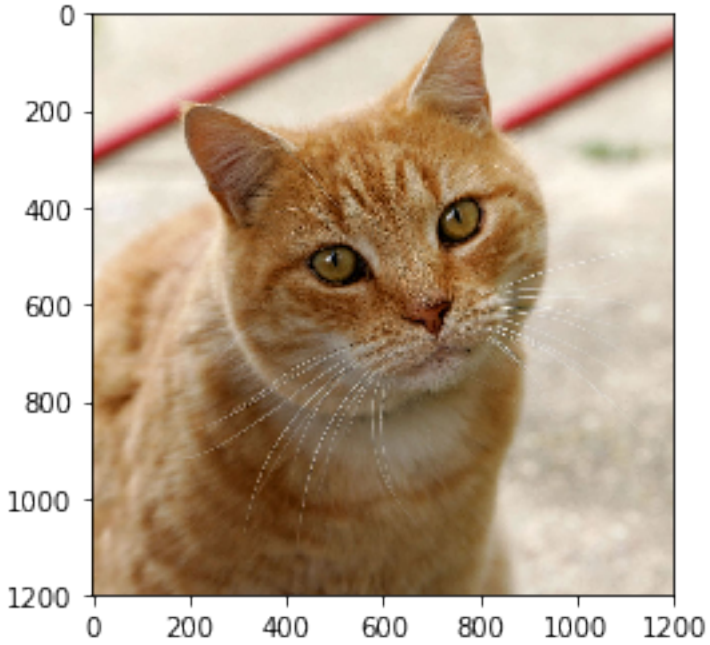
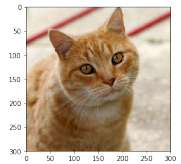


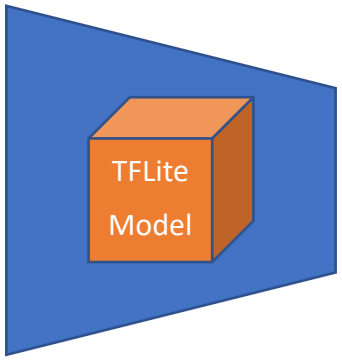
(1200, 1200, 3)

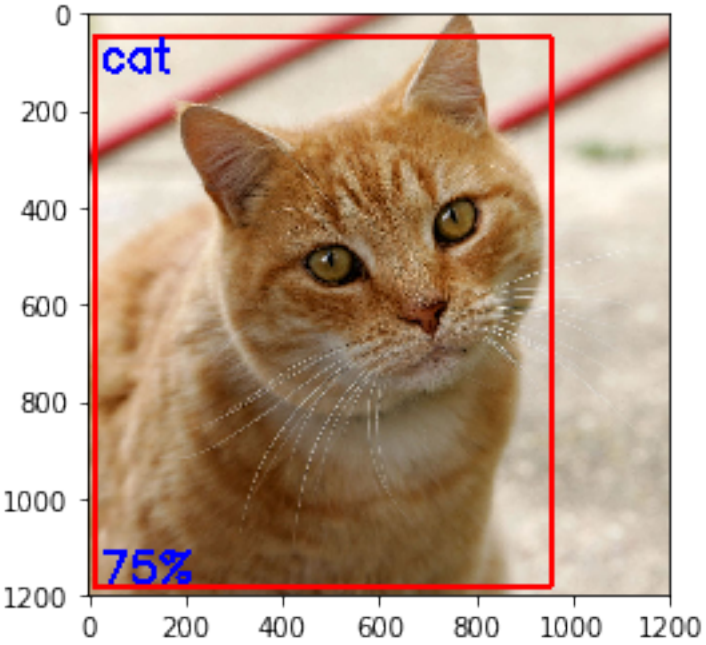
Pre-Process



(1, 300, 300, 3)

TFLite Interpreter





[{'bounding_box': [0.04125446,
0.01441014,
0.9867869 ,
0.79658735]
'class_id': 16.0,
'score': 0.7578125}]

Bounding Box- Object Detection

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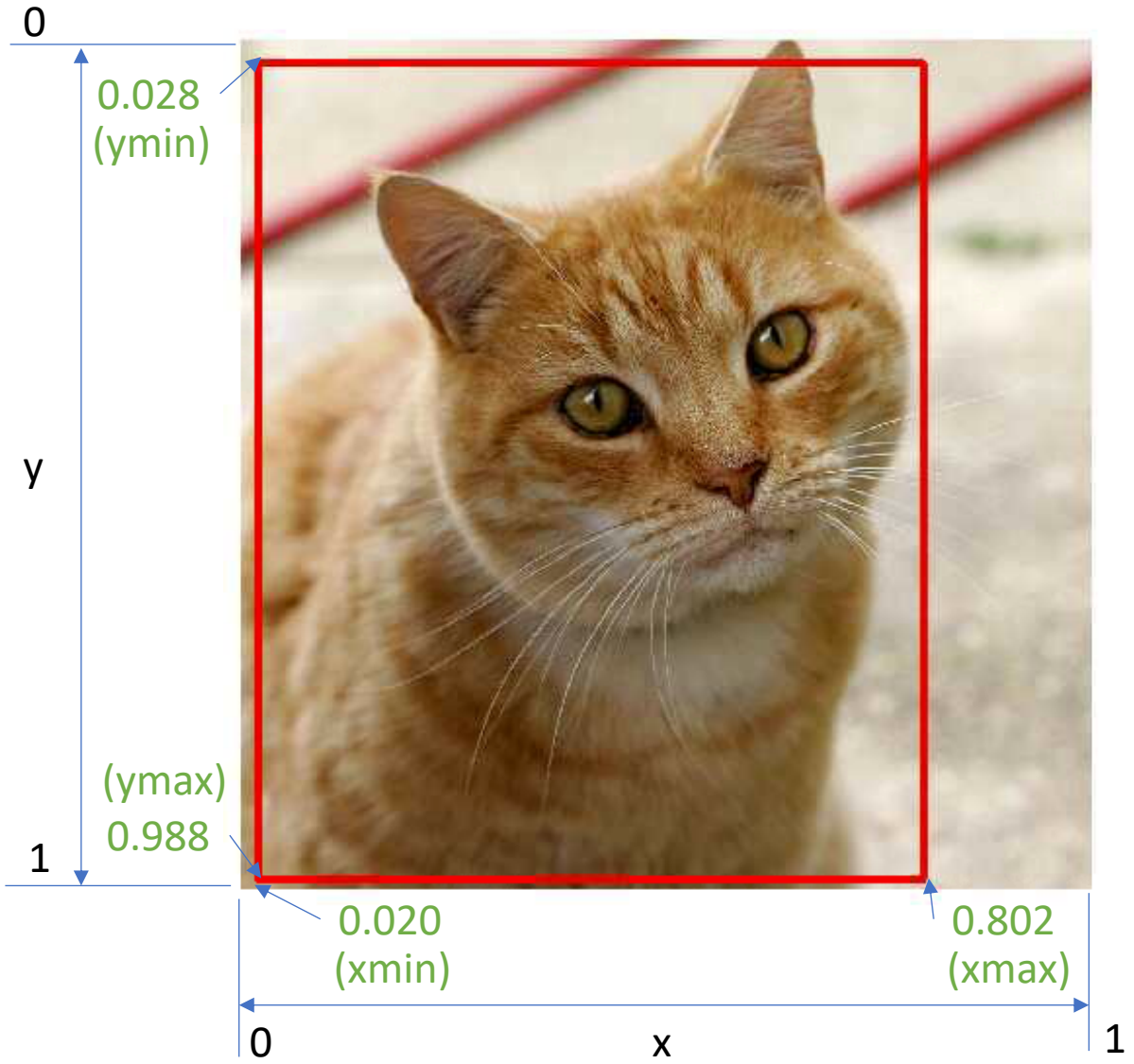

TF Lite Inference – Demo - Results

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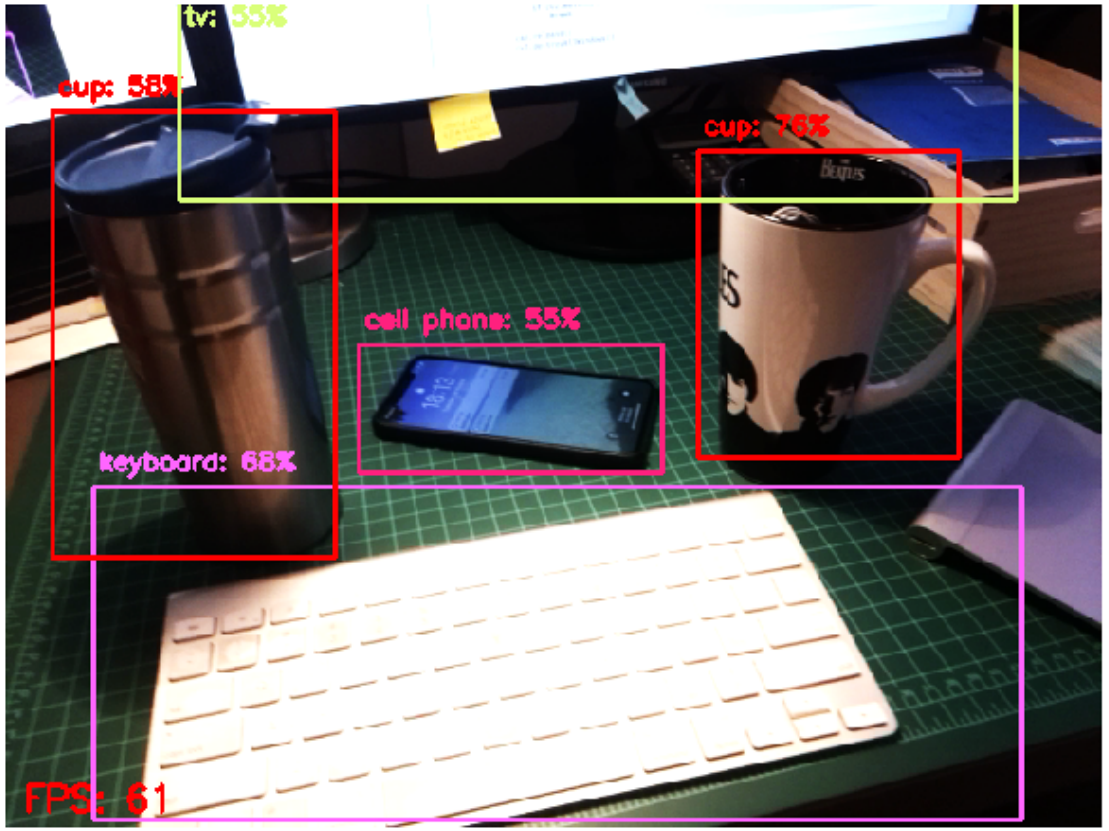
Photos



Live Video

TF Lite Inference – Other applications

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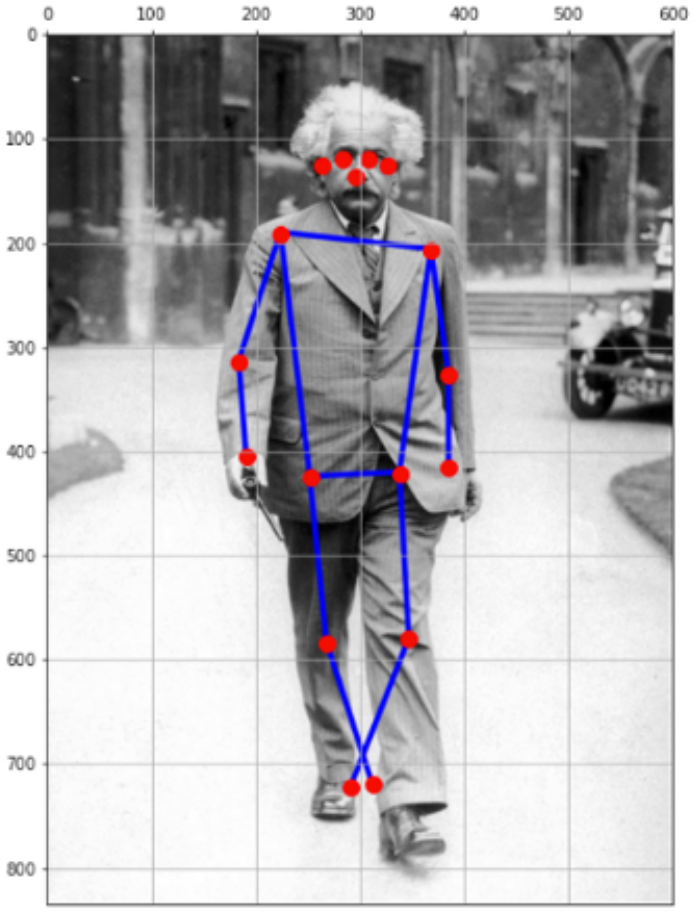
Pose Estimation on RPi



TinyML

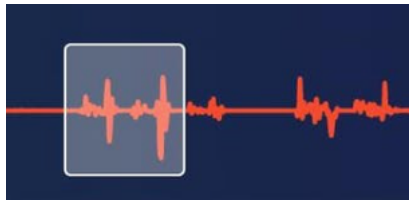
– Machine Learning on Ultra-Low-Power Microcontrollers

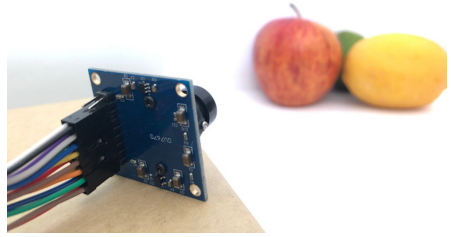
The world of Embedded devices:

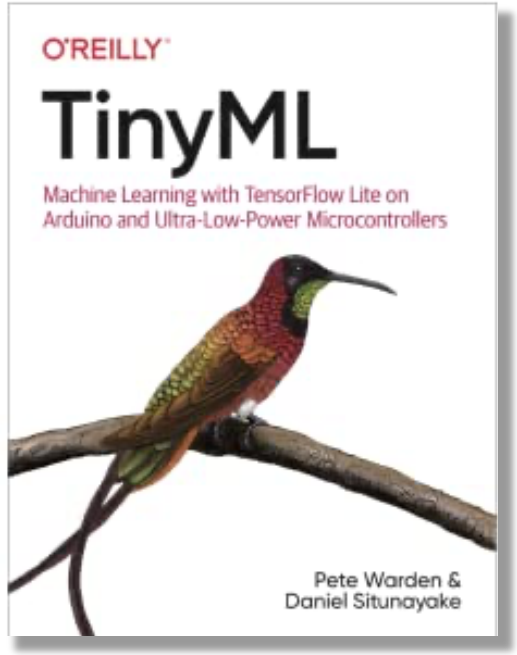
- Run a neural network model at an energy cost of below 1 mW
- Devices that can run on coin battery by a year
- 32 bit Microcontrollers that cost less than $1
- ARM's Cortex-M series of chips

Apllications as:

- Speech Recognition (Wake-Word Detection)
- Detecting Gestures (iWatch)
- Detection of Objects on camera







Learning more about Edge AI

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- **Deploy machine learning models on mobile and IoT devices:**
  - https://www.tensorflow.org/lite

- **Teachable Machine**: Train a computer to recognize your own images, sounds, & poses:
  - https://teachablemachine.withgoogle.com

- **Machine Learning on Mobile and Edge Devices with TensorFlow Lite: Daniel Situnayake at QCon SF**
  - https://www.infoq.com/news/2019/11/tensorflow-lite-edge-qconsf/

- **What is Edge AI? Machine Learning + IoT**
  - https://www.digikey.com/en/maker/projects/what-is-edge-ai-machine-learning-iot/4f6558313894113 8aaad62c170827af

- **Exploring AI at the Edge!**
  - https://towardsdatascience.com/exploring-ia-at-the-edge-b30a550456db

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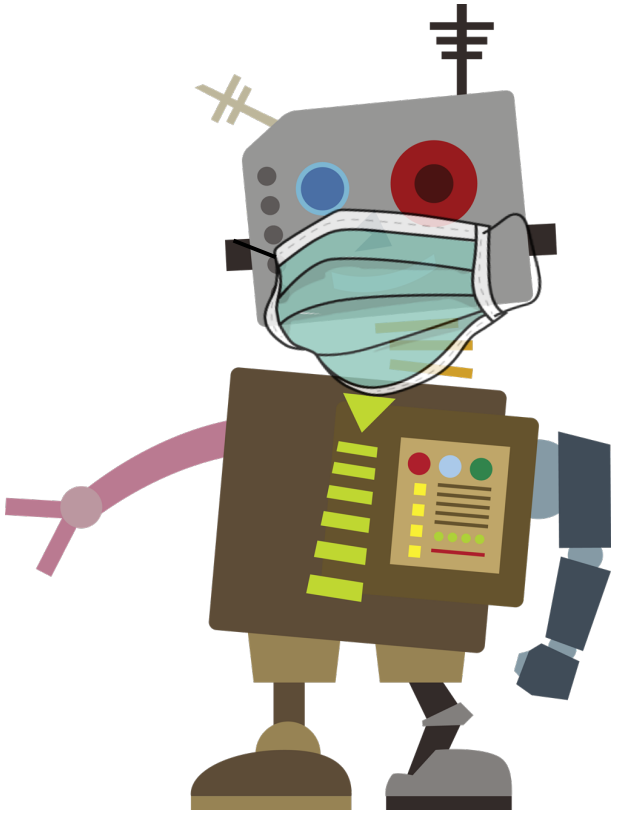
"To infinity and beyond!"



MJRoBot.org

github.com/Mjrovai

hackster.io/mjrobot

medium.com/@rovai

instructables.com/member/mjrovai

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Thanks

And keep safe!