POLITECNICO DI TORINO

# EuroDrying'2019
## 7th European Drying Conference

# Recognition of inlet wet food into drying process through a deep learning approach

*Politecnico di Torino, Italy – July 10-12, 2019*

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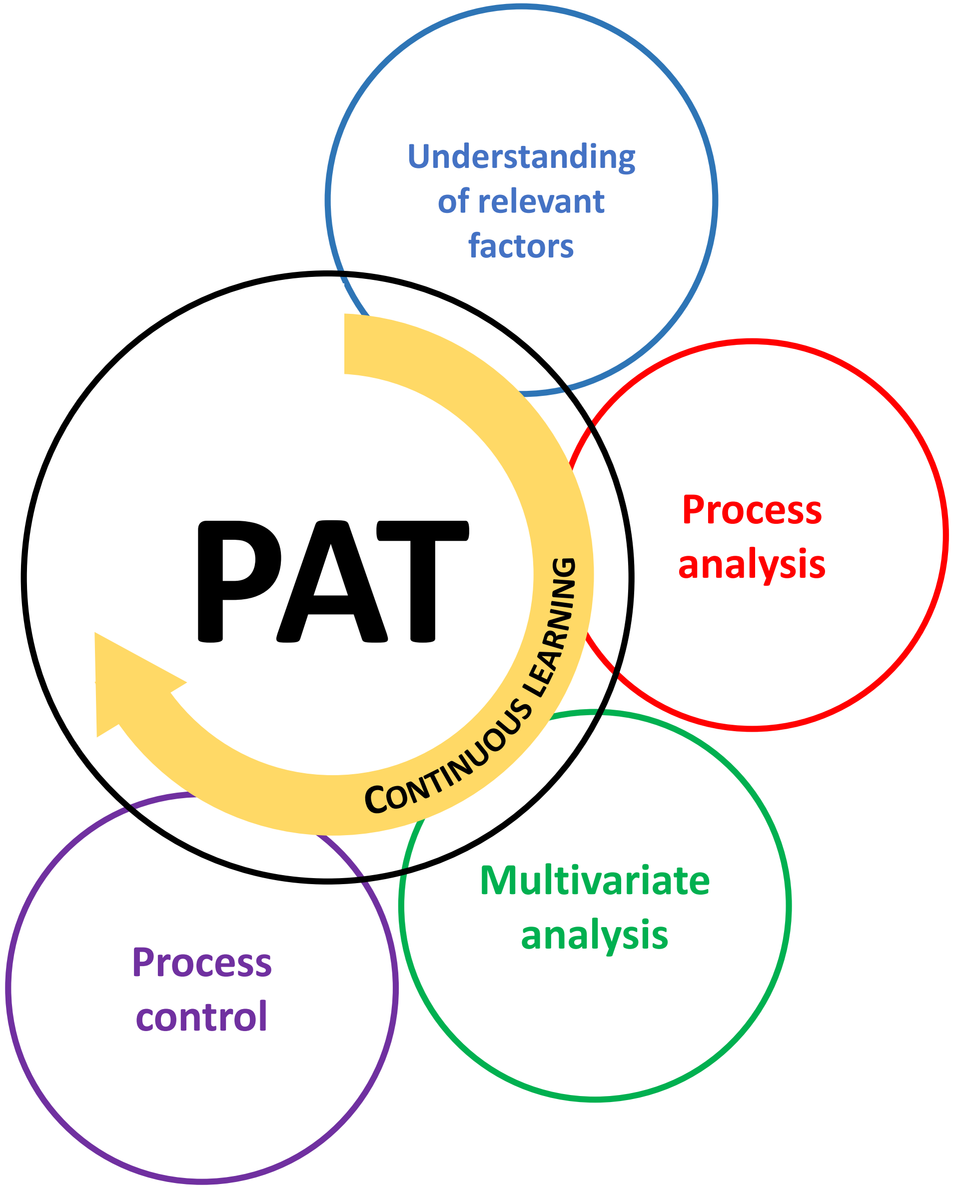
**Project of excellence**
Landscape 4.0

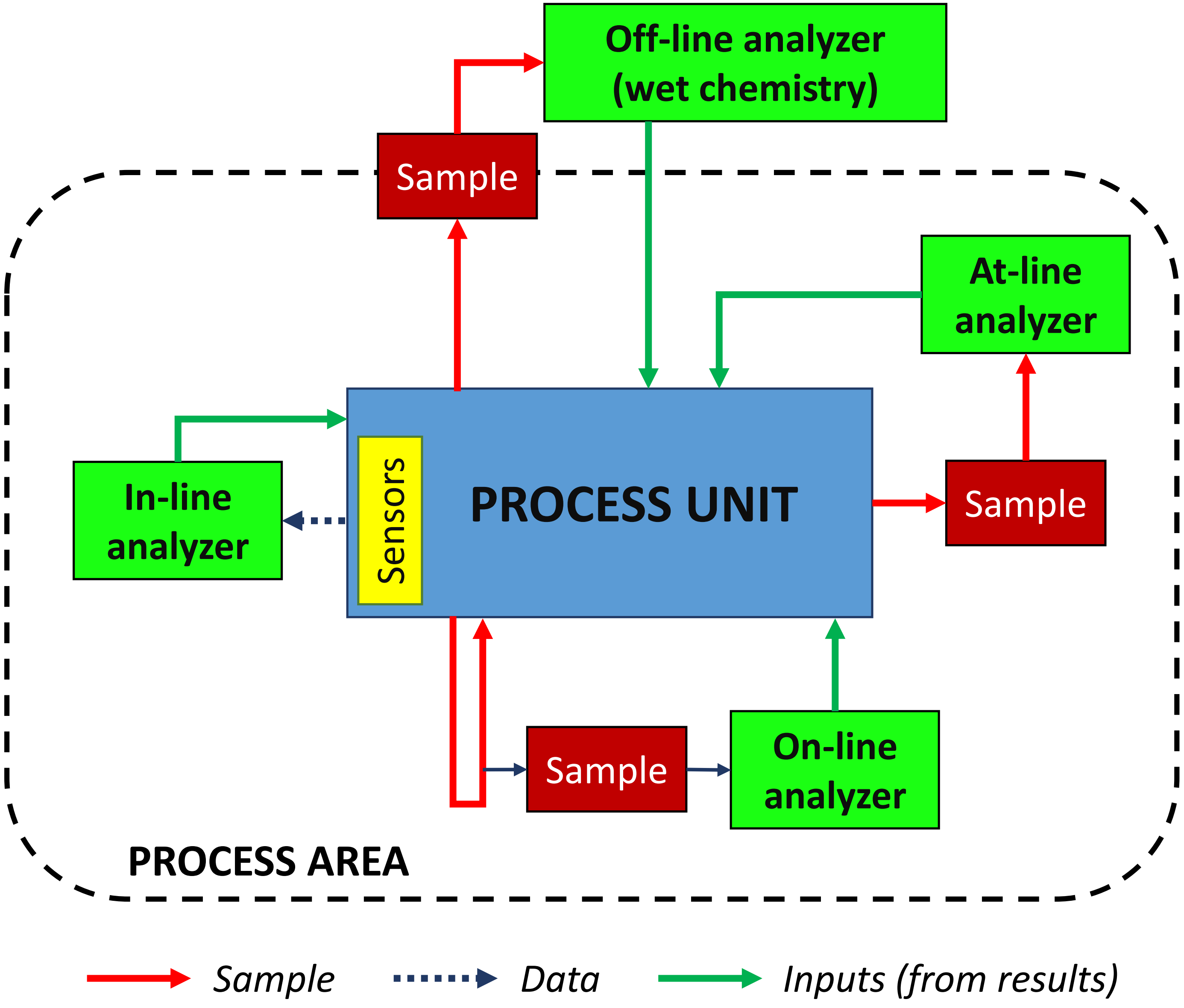
ITALIAN MINISTRY OF EDUCATION, UNIVERSITY AND RESEARCH

Sus Org PLUS

CORE organic

UNIVERSITÀ DEGLI STUDI DELLA Tuscia


Understanding of relevant factors
Process analysis
PAT
CONTINUOUS LEARNING
Multivariate analysis
Process control


Off-line analyzer (wet chemistry)
Sample
At-line analyzer
In-line analyzer
Sensors
PROCESS UNIT
Sample
Sample
On-line analyzer
PROCESS AREA
Sample
Data
Inputs (from results)

# » Our pilot dryer | *Hardware and software*

Light source

Glass

Trays

HARDWARE | CMOS camera (it generates data)

- » 2/3 inch Sony CMOS Pregius sensor
- » 2448×2048 (5 MP), up to 38 fps
- » Global shutter
- » Trigger and I/O inputs

SOFTWARE | Jupyter (data handling and modeling)

jupyter, python, OpenCV, NVIDIA CUDA, R, PYTORCH, fast.ai

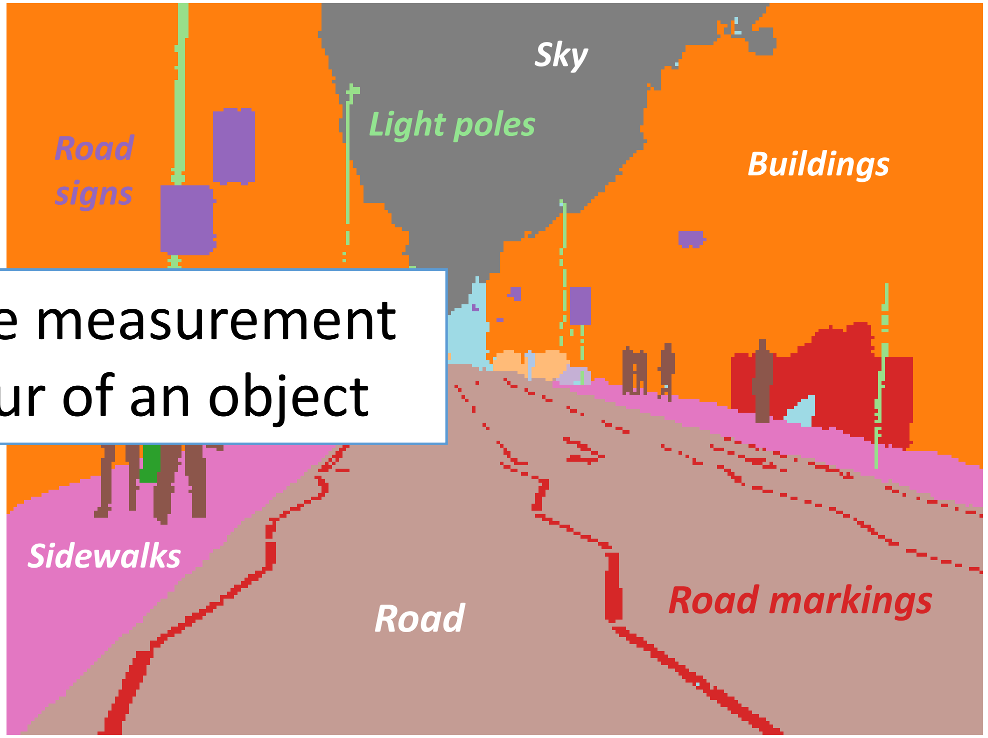
HARDWARE | NVIDIA GPUs (modeling)


- » 4608 CUDA Cores / GPU
- » 72 Ray Tracing Cores / GPU
- » 576 Tensor Cores / GPU
- » 14.2-28.5 TFLOPS / GPU

# » What does CV applied to a dryer have to deal with? | The image segmentation problem…

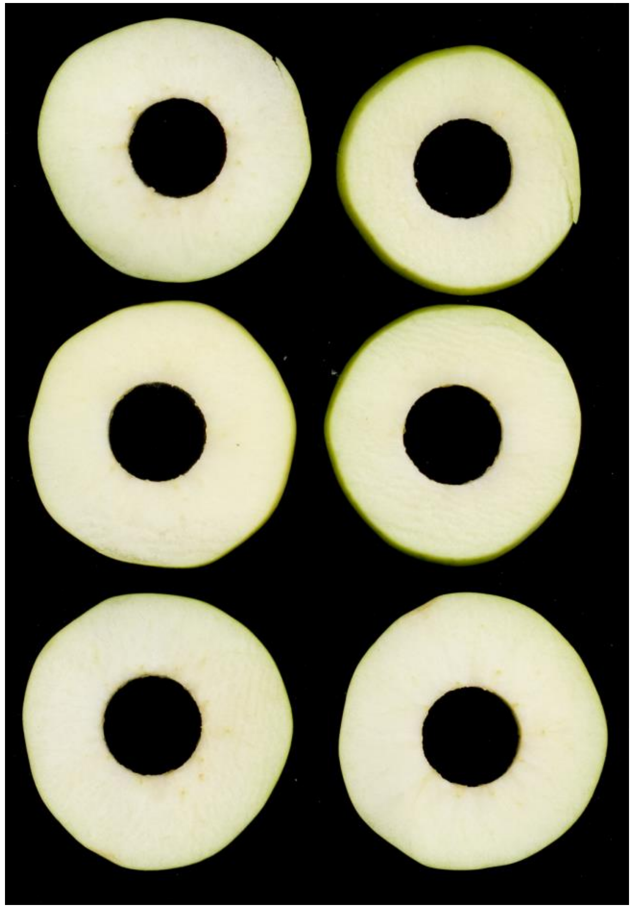
- ***Classical segmentation*** consists in splitting an image into several coherent parts, without any attempt to understand what these parts represent
- ***Semantic segmentation*** attempts to partition the image into semantically meaningful parts, and to classify each part into one of the pre-determined classes

Segmentation allows the measurement of shape, size and colour of an object

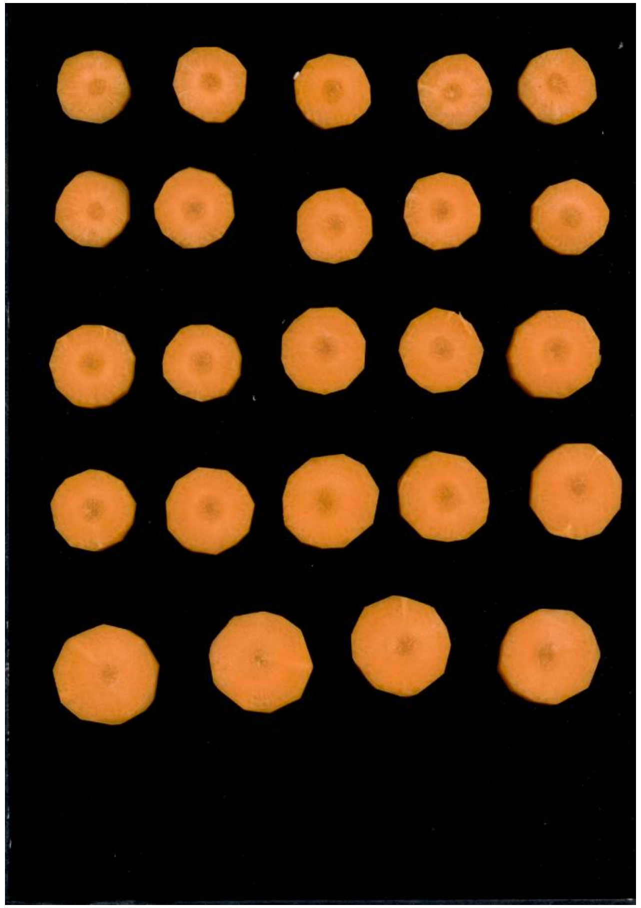


## » What does CV applied to a dryer have to deal with? | The image recognition problem…

Recognize a product and set the proper process parameters (temperature, air flow and relative humidity)



*Apple slices*

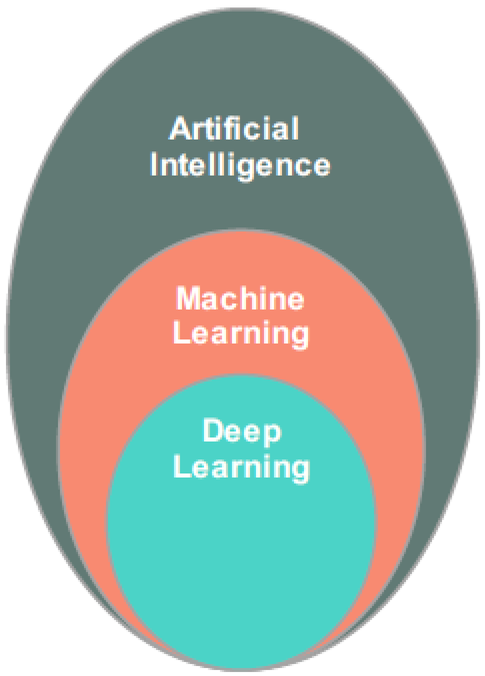


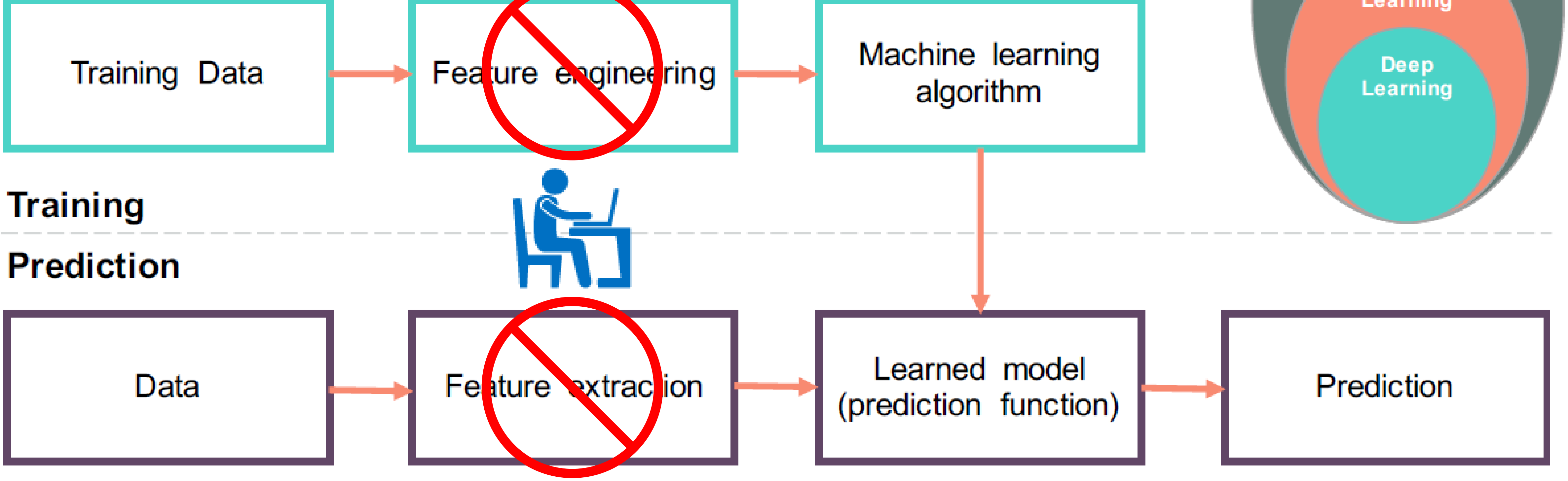
*Carrot slices*

*Cucumber slices*

## » Artificial Intelligence | *Machine learning vs deep learning*

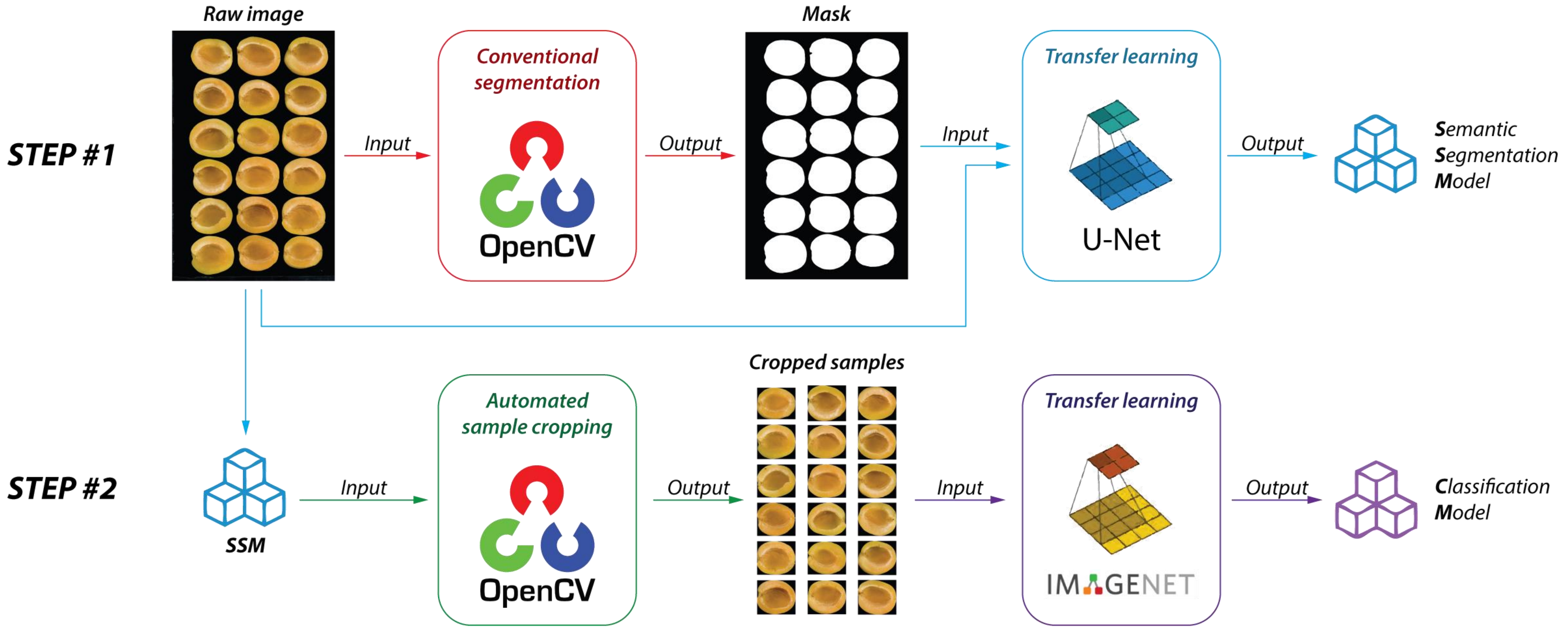
Machine learning requires feature engineering, while deep learning does not require it: *algorithm automatically learns how to perform feature extraction and which features are important for the model*



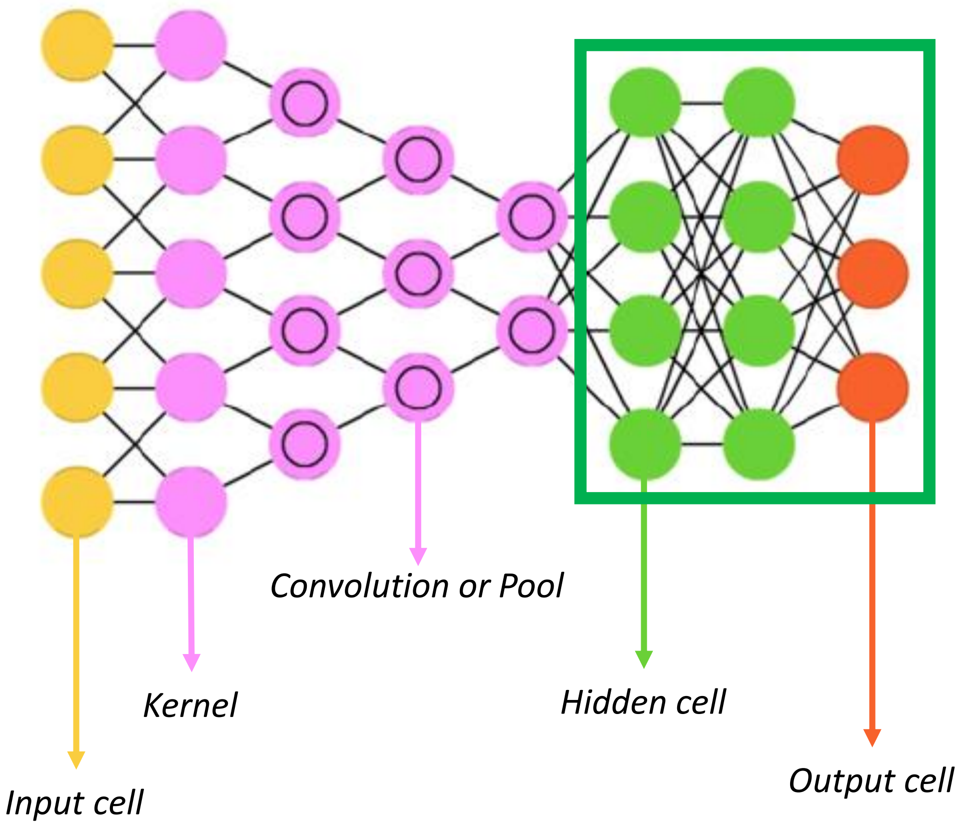

*Modified from: Sorin Cheran's presentation titled 'About AI' (2018)*

# » Our DNN approach | *Semantic segmentation and Image classification*



# » How to make the model training much easier | *the transfer learning approach*

Transfer learning is a technique that shortcuts much of this by taking a piece of a model that has already been trained on a related task and reusing it in a new model (source: Google Tensorflow website, 2019)




Last layers are the only ones that are retrained

# » The dataset | *100+ images per class of product*

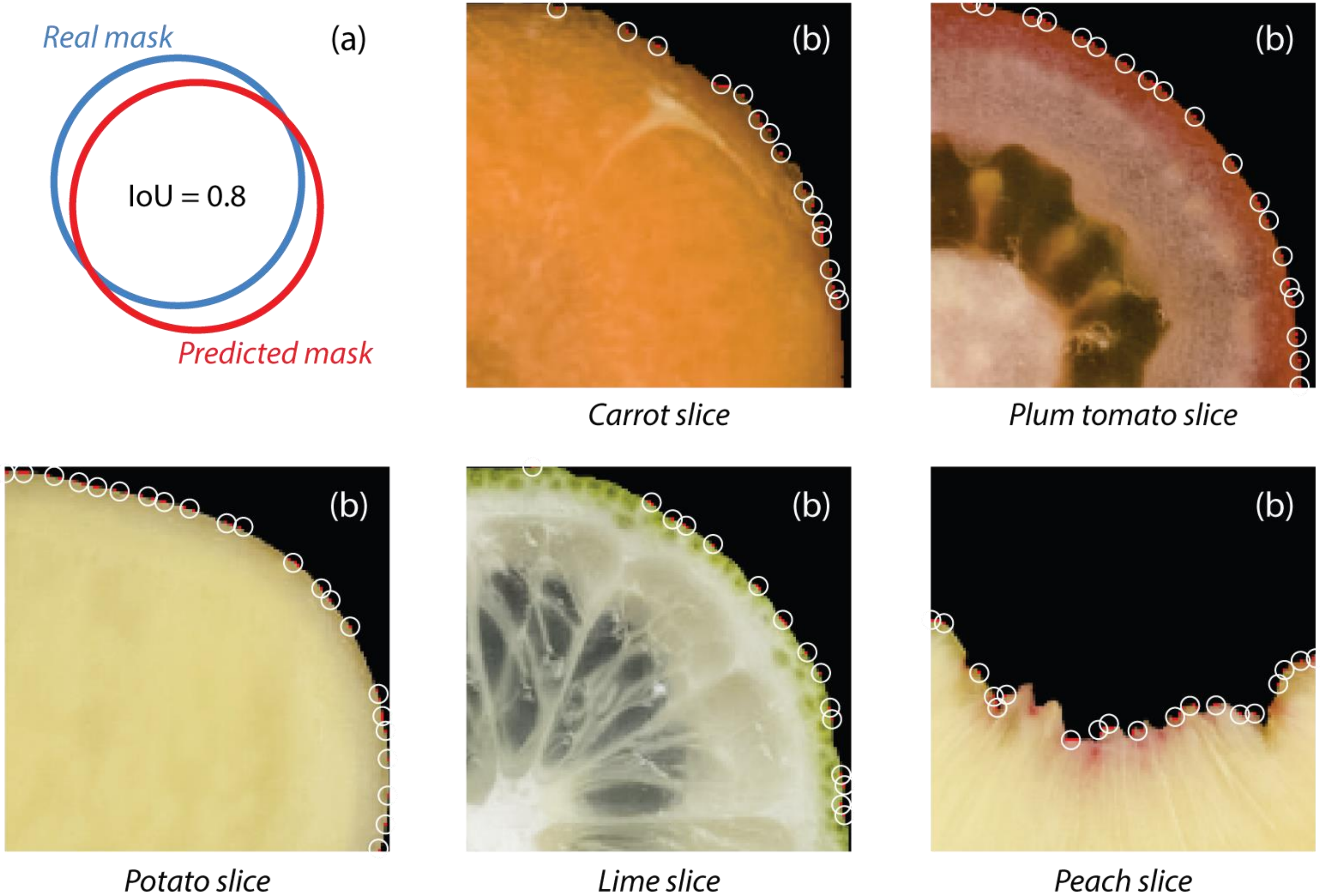
1. Apricot
2. Banana
3. Carrot
4. Cucumber
5. Champignon (or white button, mushroom)
6. Cherry
7. Onion
8. Kiwifruit
9. Lime
10. Apple
11. Potato
12. Chilli pepper
13. Pear
14. Peach
15. Red plum
16. Zucchini
17. Cherry tomato
18. San Marzano tomato

Calibration set 70% - Prediction set 30%

CNN models were retrained by perfoming data augmentation

# » **Results** | *Semantic segmentation*

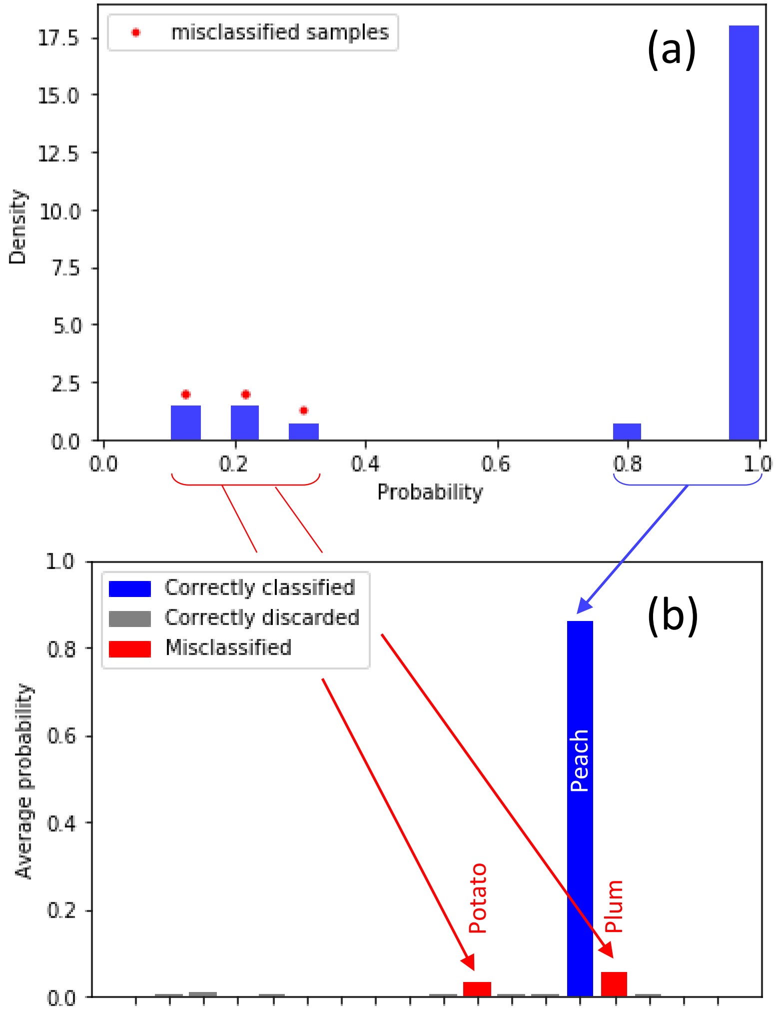
Intersection over Union
IoU > 99%




*Example of IoU (a) and images of samples with misclassified pixels (b)*

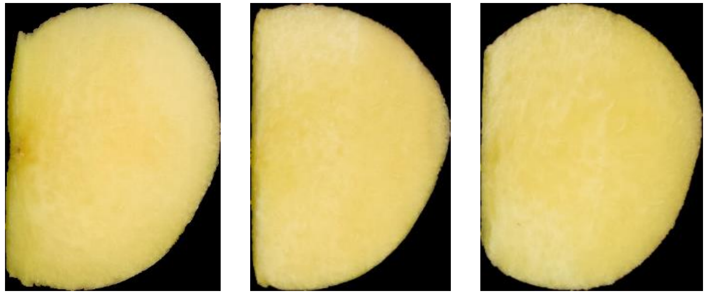
# » **Results** | *Product recognition*

Model performance
Accuracy = 0.992




› Peach slices misclassified as red plum slices

› Peach slices misclassified as potato slices



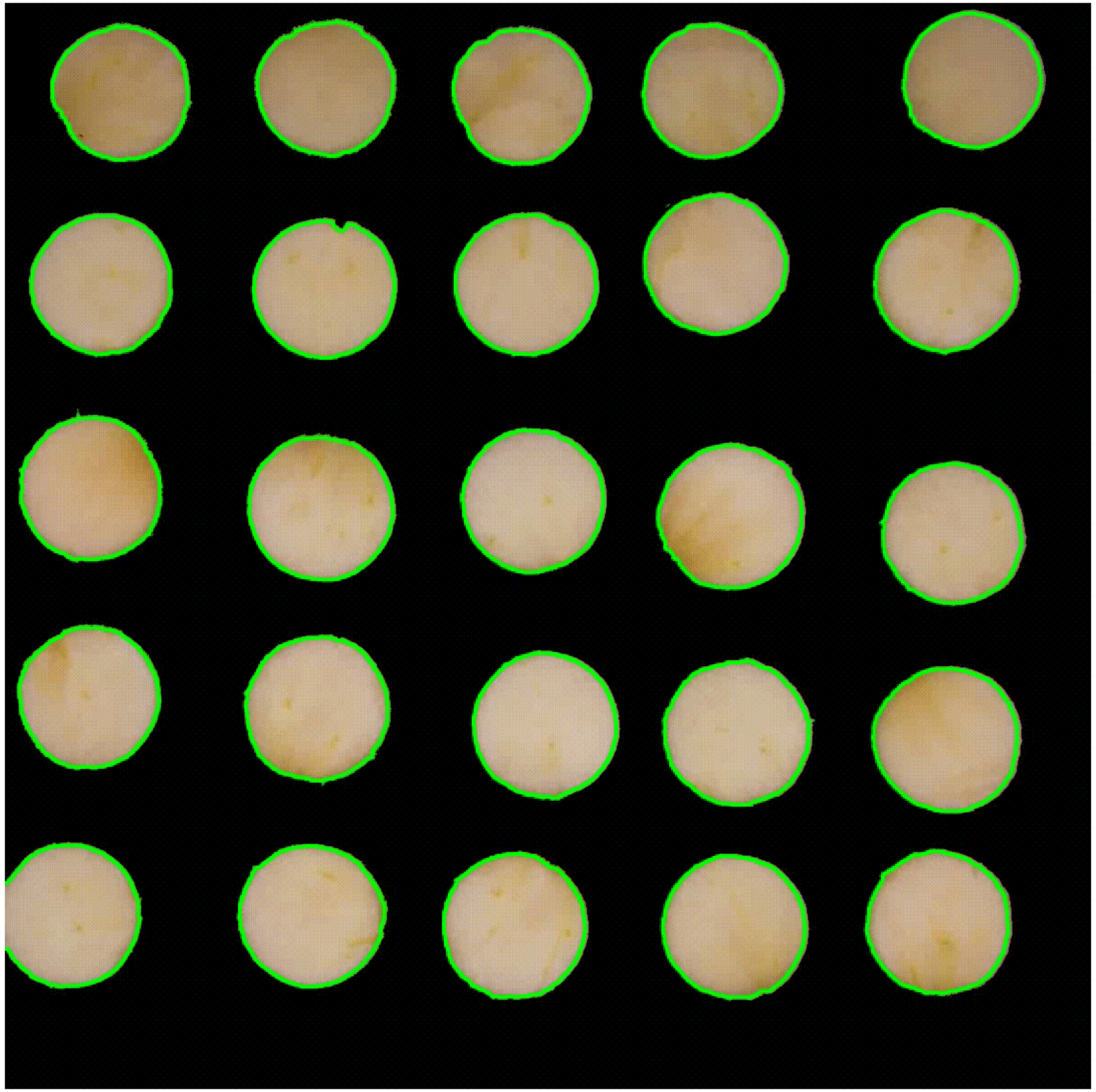
## » Results | *Training performance: comparison between CPU and GPU*

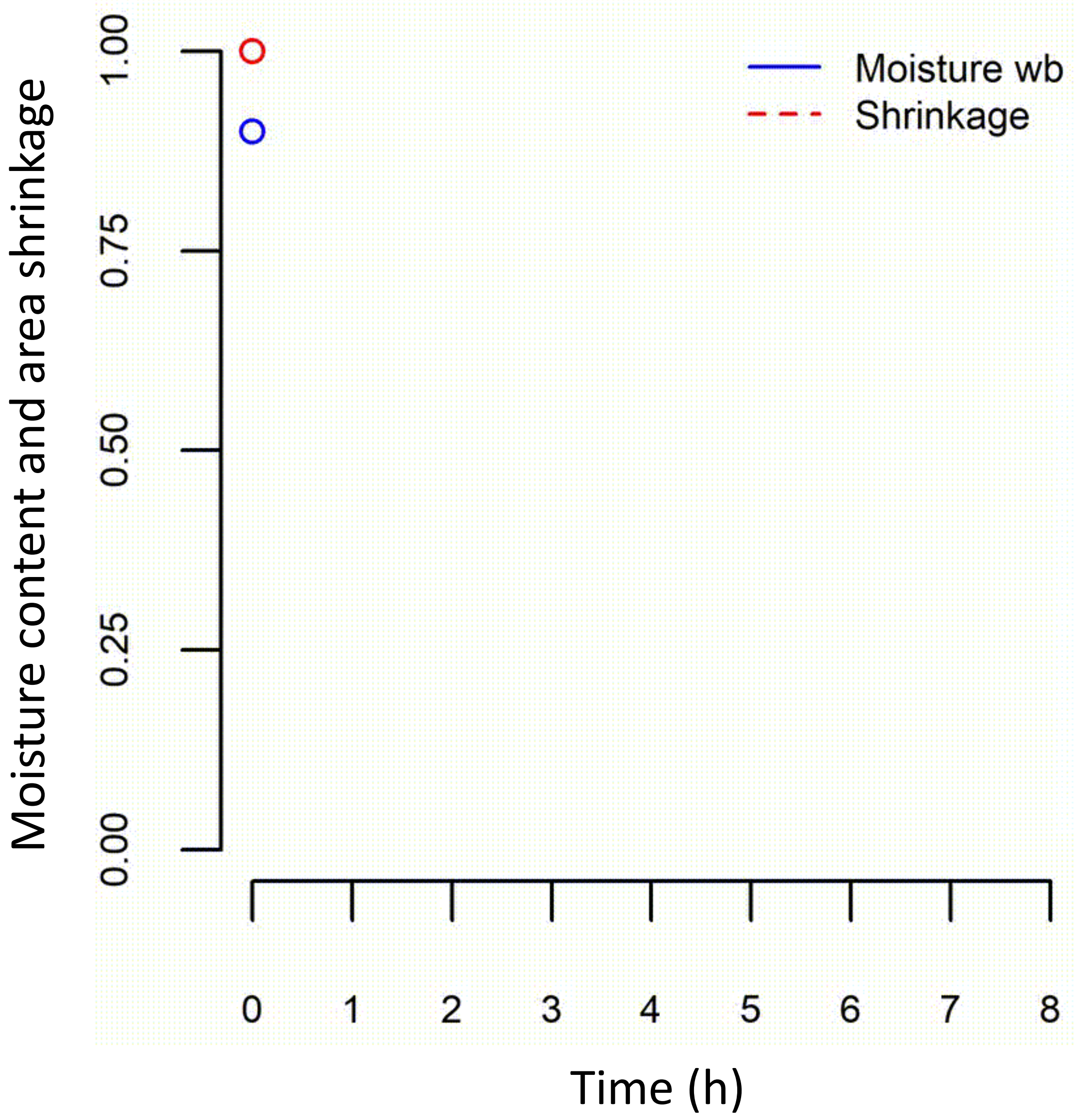
| Model | Learning rate | Epochs | Batch size | Runtime system | Training time (hh:mm:ss) |
|---|---|---|---|---|---|
| CM | 1E-03 | 3 | 64 | CPU | 00:07:47 |
| | | | | GPU | 00:00:26 |
| SSM | 5E-05 | 10 | 8 | CPU | 06:44:03 |
| | | | | GPU | 00:22:31 |

CM: classification model
SSM: semantic segmentation model

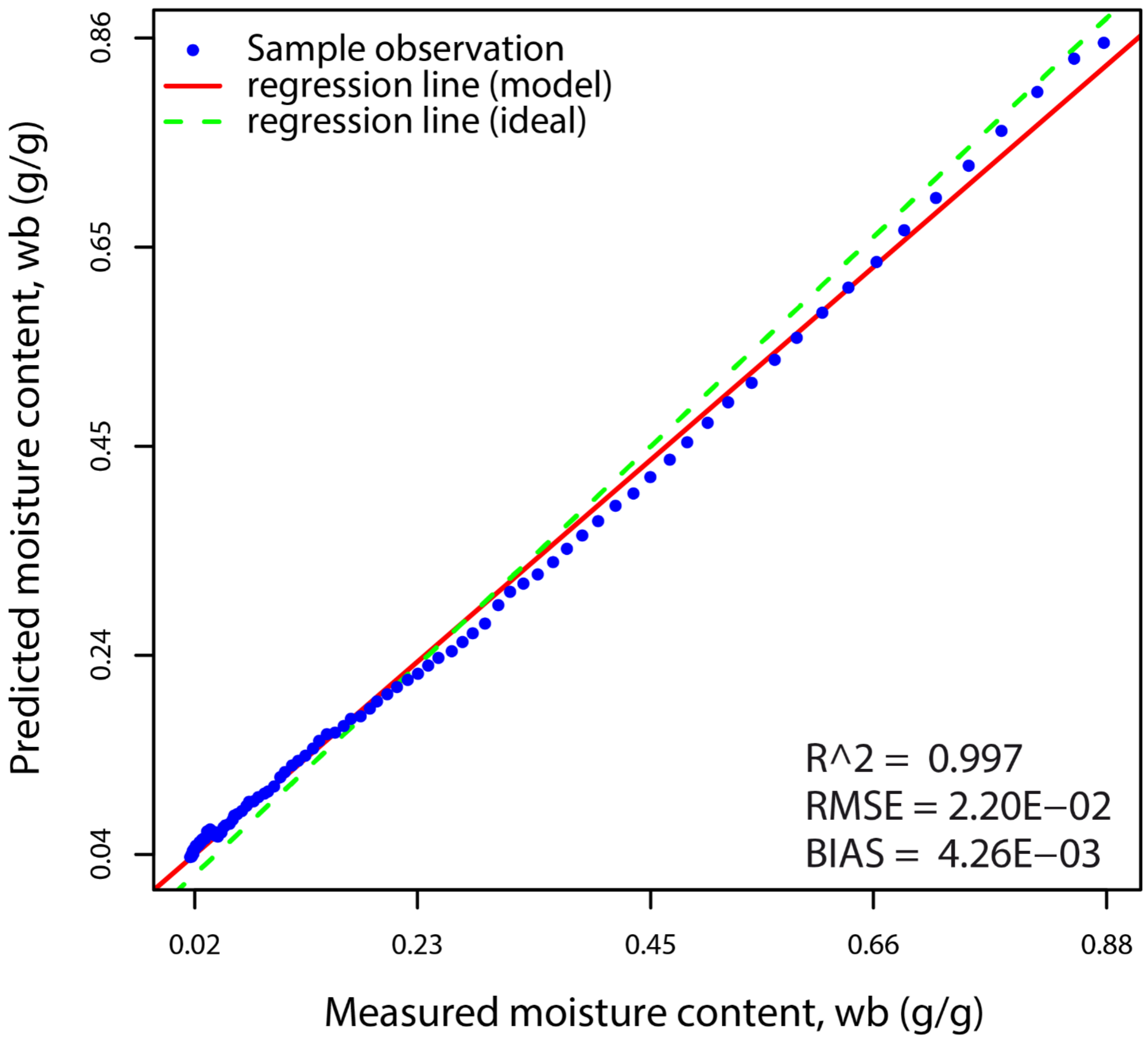
CPU mod. Ryzen 5 1400 (AMD Inc. CA, USA)
GPU mod. RTX 2070 8 GB (NVIDIA Corp. CA, USA).

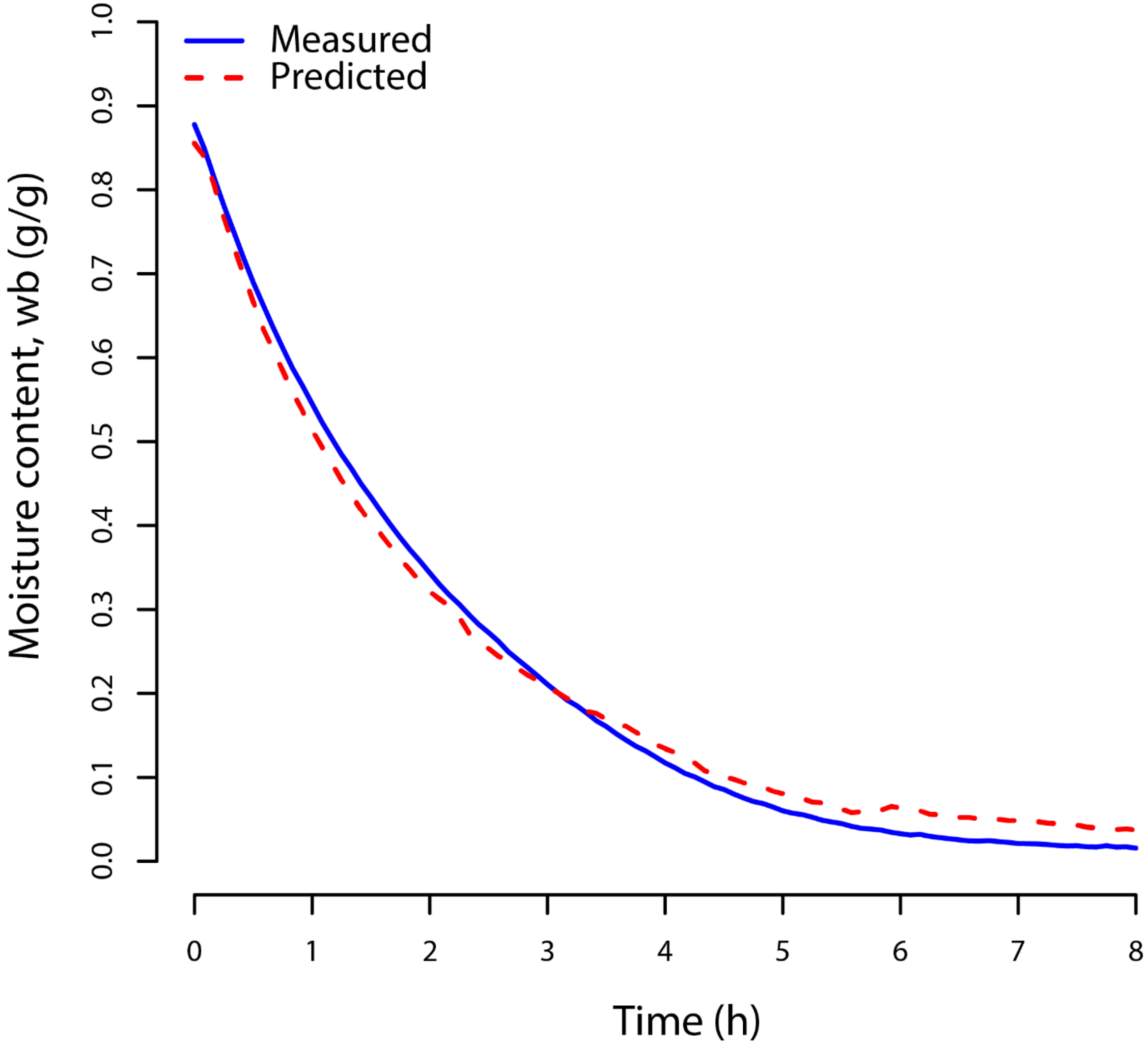
## » **Results** | *Shape and size measurements*



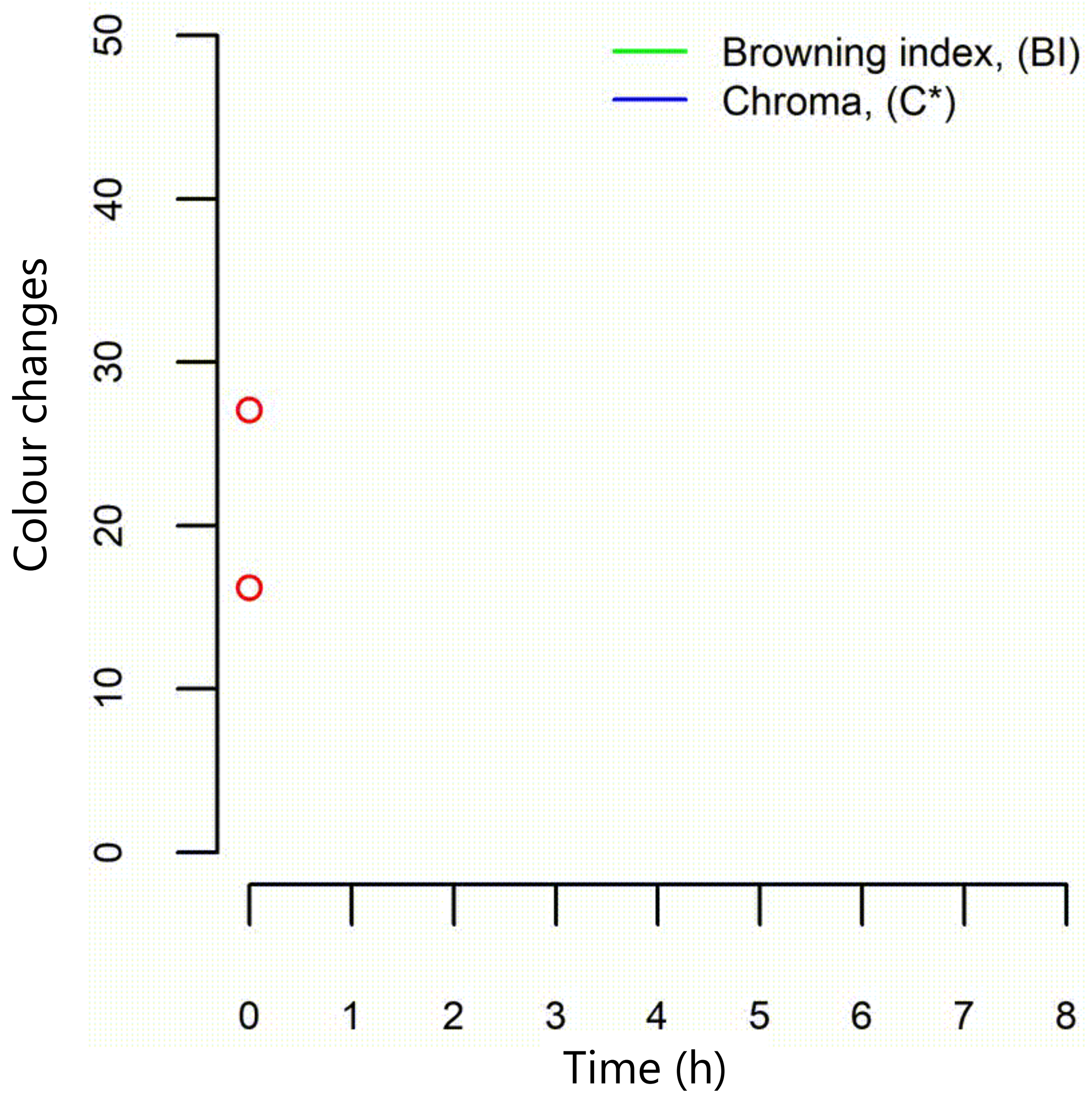


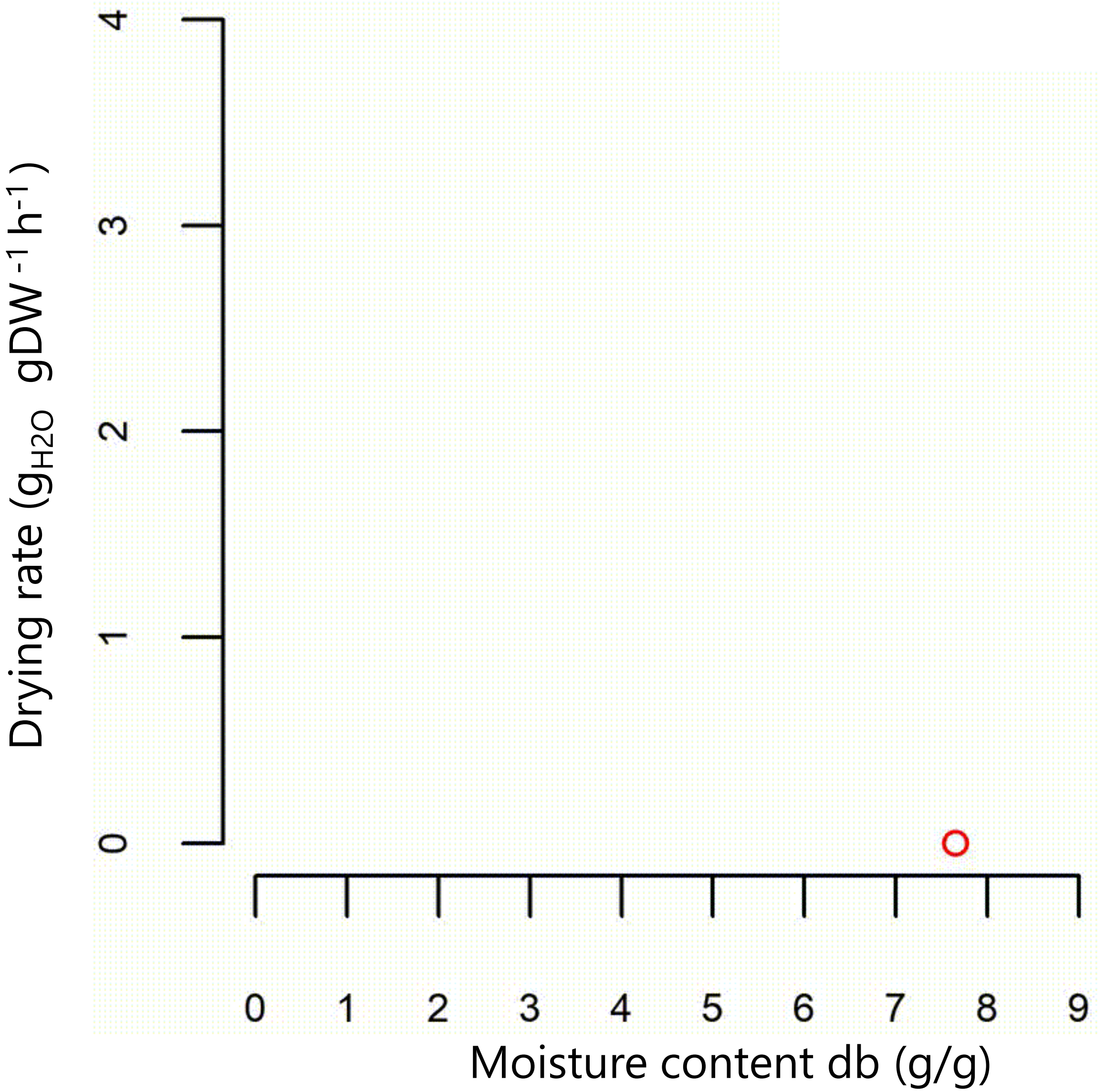
# » **Results** | *Prediction of changes in moisture content*



# » **Results** | *Changes in colour and trend of the drying rate*



» **Next step?** | *The implementation of CNNs in a drier*

# JETSON NANO DEVKIT SPECS

| | PROCESSOR |
|---|---|
| CPU | 64-bit Quad-core ARM A57 @ 1.43GHz |
| GPU | 128-core NVIDIA Maxwell @ 921MHz |
| Memory | 4GB 64-bit LPDDR4 @ 1600MHz ∣ 25.6GB/s |
| Video Encoder | 4Kp30 ∣ (4x) 1080p30 ∣ (2x) 1080p60 |
| Video Decoder | 4Kp60 ∣ (2x) 4Kp30 ∣ (8x) 1080p30 ∣ (4x) 1080p60 |

| | INTERFACES |
|---|---|
| USB | (4x) USB 3.0 A (Host) ∣ USB 2.0 Micro B (Device) |
| Camera | MIPI CSI-2 x2 (15-position Flex Connector) |
| Display | HDMI ∣ DisplayPort |
| Networking | Gigabit Ethernet (RJ45, PoE) |
| Wireless | M.2 Key-E with PCIe x1 |
| Storage | MicroSD card (16GB UHS-1 recommended minimum) |
| 40-Pin Header | UART ∣ SPI ∣ I2C ∣ I2S ∣ Audio Clock ∣ GPIOs |
| Power | 5V DC (µUSB, Barrel Jack, PoE) - 5W ∣ 10W |
| Size | 80x100mm |

*Source: deleveloper.nvidia.com (2019)*

## » Next step? | *Make the CNN models sensitive to differences in products size and shape*

**CURRENT APPROACH**

Peach slices misclassified as…

Red plum slice

Potato slice

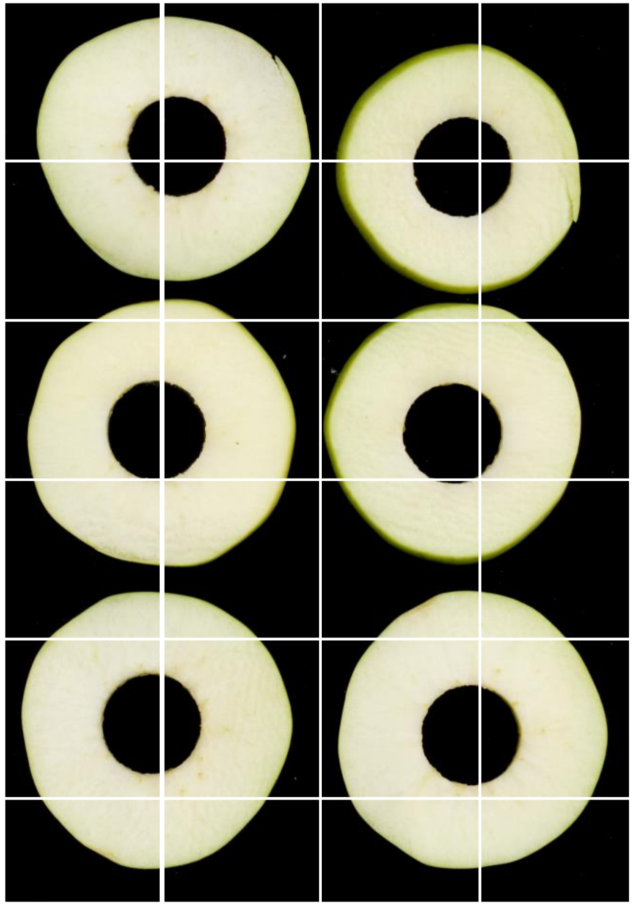
*Resize and reshape*

Red plum slice

Potato slice

***Size and shape features are partially lost***

**NEW APPROACH**

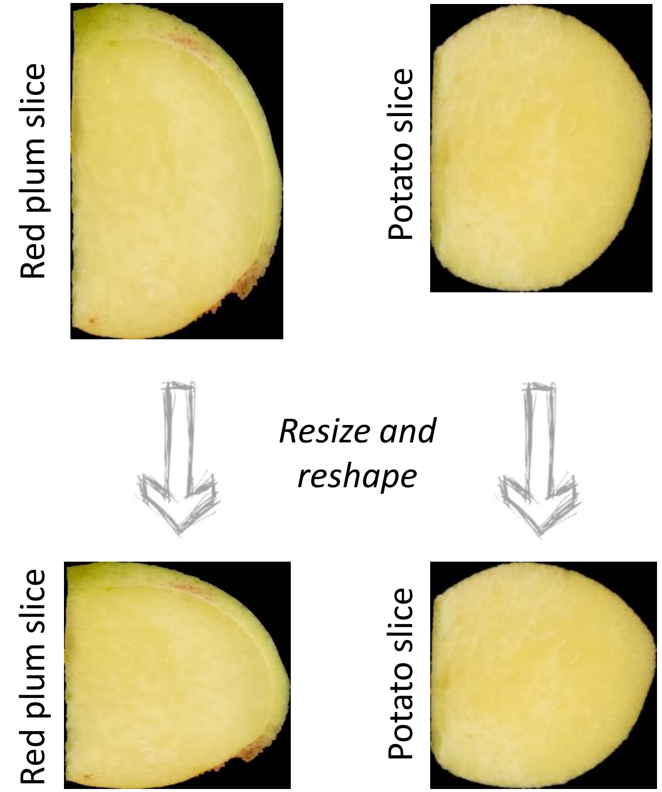


* Peach slices misclassified as…

## » Next step? | *Make the CNN models sensitive to differences in products size and shape*

**CURRENT APPROACH**

Peach slices misclassified as…




***Size and shape features are partially lost***

**NEW APPROACH**

***Size and shape features are fully available***

# THANK YOU FOR YOUR ATTENTION