HAEmbedded and Edge AI project: **Fruit Eye Link**

Students: Daniele Sinigaglia & Vicente Castro
Group Name: BlowYourHat

In 2019, 1 in 3 people reported not consuming any fruit or vegetable daily

Only 12% of the population reached the recommended daily consumption


0,000
0,000
0,00
0,00
OMEGAbilance
SLAM NEXT
SCONTO -30%
2,79

Contents

BUSINESS ASPECTS

ETHICAL PERSPECTIVES

TECHNOLOGICAL SOLUTION

FUTURE DIRECTION

POLITECNICO
MILANO 1863

Business

Market and values

What the current experience?

- Customers ***need to weight the items*** to buy them.
- Customers need to ***know the item number*** or ***the name***

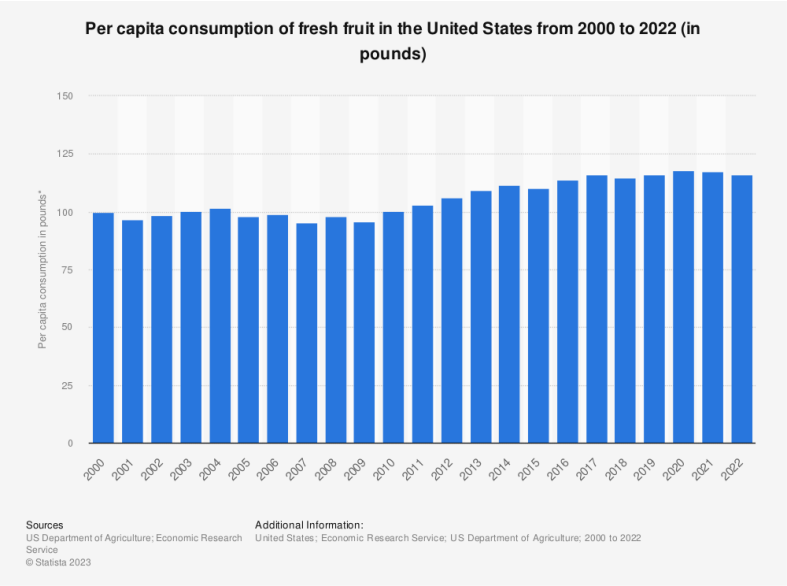
Enhancing customer experience by improving the way they buy fruits, by an ***intelligent scale***!

A market perspective

The ***fresh products*** department is the main determinants among consumers when selecting a grocery store

- ***New interests*** in healthy diet!
- New ***automatized stores*** (e.g. belgian supermarket)

Customer satisfaction plays a huge role in market sales!



Our target costumer

We will empower the retail sector by putting **more control** on the sales.

- We are doing this ***by improving customer experience***

Our customer are:

- Big supermarkets
- Fruits stores

Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Our solution

- Based on a ***list of fresh products***.
- Customer interacts with the scale ***to print the label.***
- ***Customer selects*** the predicted category.

The portion of fruit must be inside a bag or loose, so that the camera can see the content

Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Business - Values

- ***Customer Orientation***: The customer is at the center of every decision.
- ***Sustainability***: A commitment to sustainable business practices.
- ***Innovation***: The adoption of new technologies and processes to improve operational efficiency and customer experience.

Customer Orientation

Putting customer needs at the heart of the business you ***increase profit***.

- The removed repetitive tasks leave space for imagination and inspiration.
- Workers have an increased commitment to the public.

Sustainability

- Efficient ***use of energy***
- Sustainable packaging are now fully sustainable without sticky labels
- ***Reducing food waste*** with more sales of fruit and vegetables

Innovation

- Old scales ***cause issues to customers and cashiers***.
- Added value and ***customer loyalty.***
- More technological stores attracts ***new categories of customers***

Author: Panuwat Dangsungnoen | Acknowledgments: 123RF
Copyright: Panuwat Dangsungnoen

POLITECNICO
MILANO 1863

Ethical Review

Privacy, inclusivity and user well-being

Ethical Aspects

Engineering design has been regarded as a form of materializing morality.

- Privacy
- Inclusivity
- Job displacement
- Good care and user well-being

Privacy

Our solution works on images given by the user.

- The camera is oriented to ***only capture the plate***
- Data and decision are ***on-device***
- *No flow of data* on the internet

Who owns the data?

Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Inclusivity

- Digital ***technology needs to be human-related***
- ***Ease of use***, by multi-modality

We need to be able to work with users from ***different contexts***

- ***No need to look*** at the labels attached to shelves
- ***"speaking"*** calculator

Job Displacement

- Automation gives to workers the ***chance to center in the real tasks***!
- Collaboration between workers and the machines.
- Need of guidelines for workers

Good care and user well-being

- ***Final decision*** will be taken ***by the customer***
- Reduction of repetitive tasks leaves space to inspiration
- Increase ***customer experience***
- Transform industry: collaboration between stakeholders, proactive policies and measures can be implemented, aiming to ensure an inclusive transition to new work models.

POLITECNICO
MILANO 1863

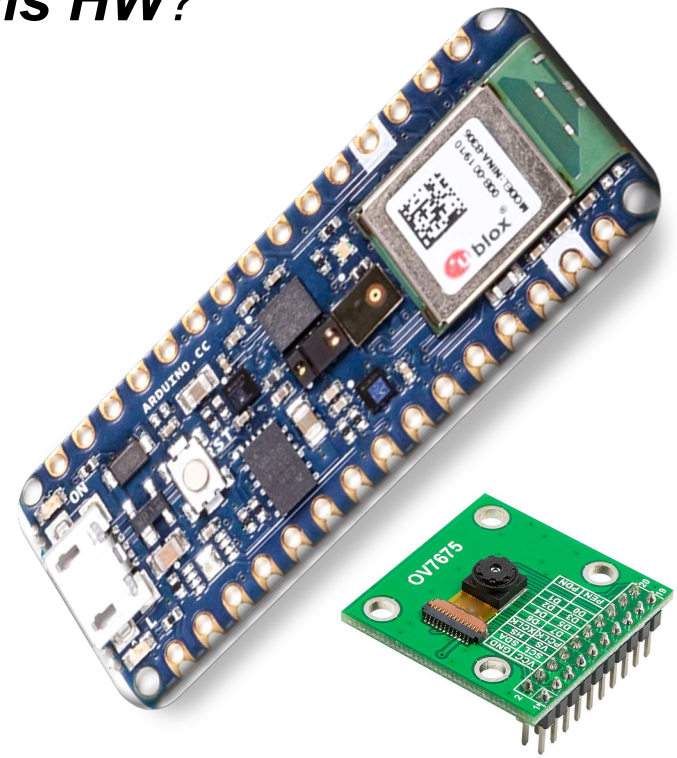
Technical Aspects

Hardware Capabilities

Initial study: ***What can be done with this HW?***

- *Memory constraints?*
- *Image acquisition pipeline?*

- **RGB565** vs RGB888 (2B vs 3B)
- Total Image size(**QCIF**, QQVGA)
- Total *memory/frame* ?

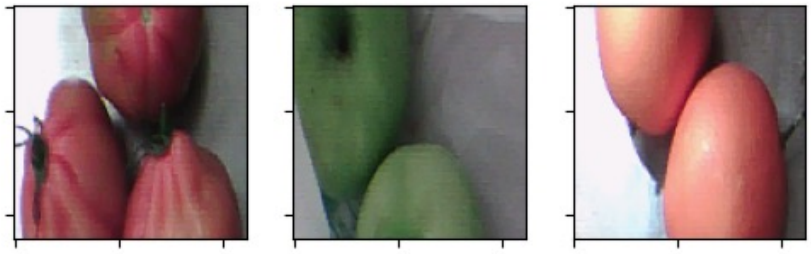


Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Receptive Field and Pre-processing

The camera doesn't have a big *Field-of-View:*

- More *than one-meter to contain* the entire fruit.
- ***Cropping*** *vs Resizing* the input.
- Transform to **RGB888**



Samples taken with OV7675

Pre-processing step on the input image

```
// Convert RGB565 (16-bits) to RGB888 (24-bits)
uint8_t baseRed = (pixelCombined & 0xF800) >> 11;
uint8_t baseGreen = (pixelCombined & 0x07E0) >> 5;
uint8_t baseBlue = (pixelCombined & 0x001F);

uint8_t red = (baseRed << 3) | (baseRed >> 2);
uint8_t green = (baseGreen << 2) | (baseGreen >> 4);
uint8_t blue = (baseBlue << 3) | (baseBlue >> 2);
```

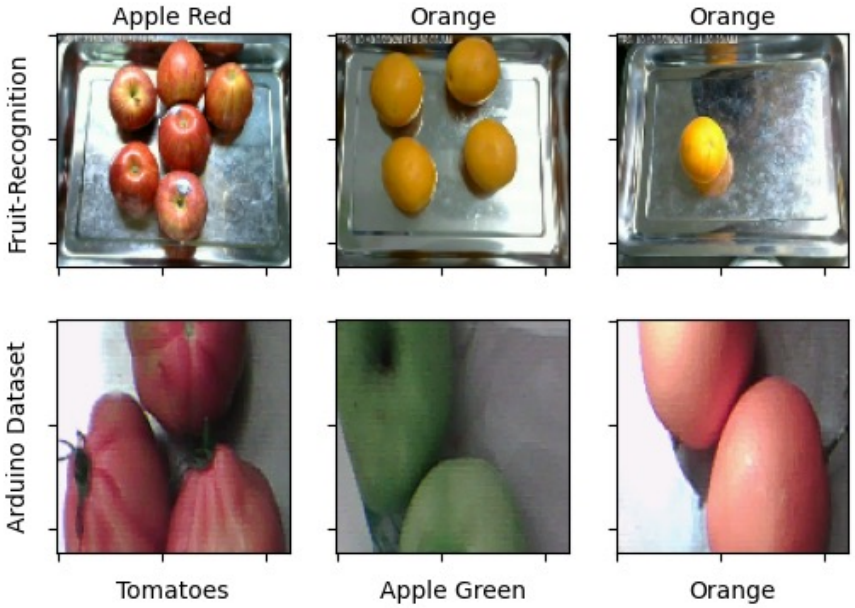
Datasets

We worked on two datasets

- *Fruit-Recognition dataset* (from Kaggle) -> ~ 7000samples
- Manually acquired ("Arduino dataset") -> 300samples

Big difference on image qualities!
+ The problem of the *FOV.*

Data Augmentation

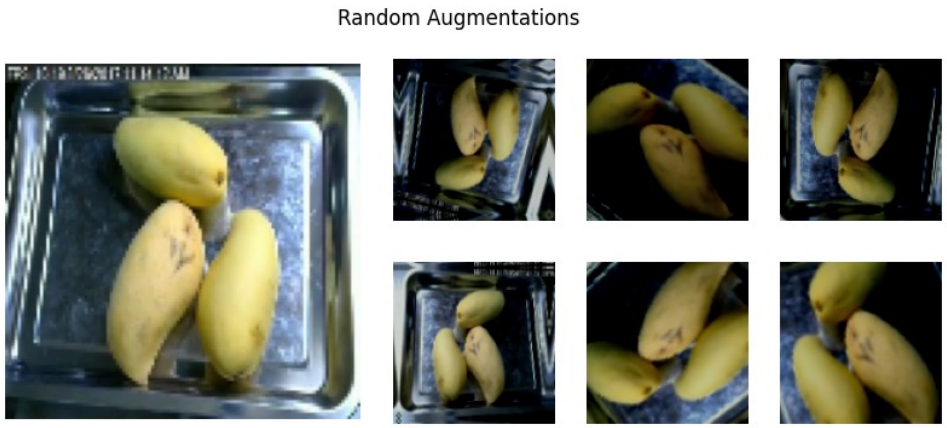


Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Dataset: Data Augmentation

Apart from a common regularization technique, it can be used to "simulate" our real-world data.

- ***ZoomIn*** (heavily used to resemble the reduced FOV)
- ***DegenerateColors*** (to simulate less precision bits)



Models: base model definition

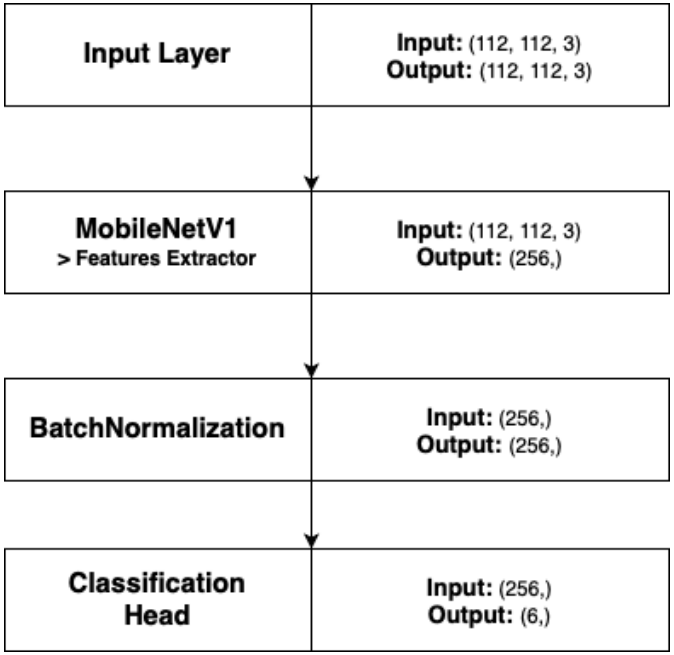
Our base model is a ***MobileNetV1* architecture**:

- Pre-trained on ImageNet with 96x96 images.
- Images are in [0..1] range

+ Add a ***BatchNormalization*** *Layer.*

+ A ***ClassificationHead*** *(DenseLayer).*

We use a 112x112 image input!!



Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Models: post-processing

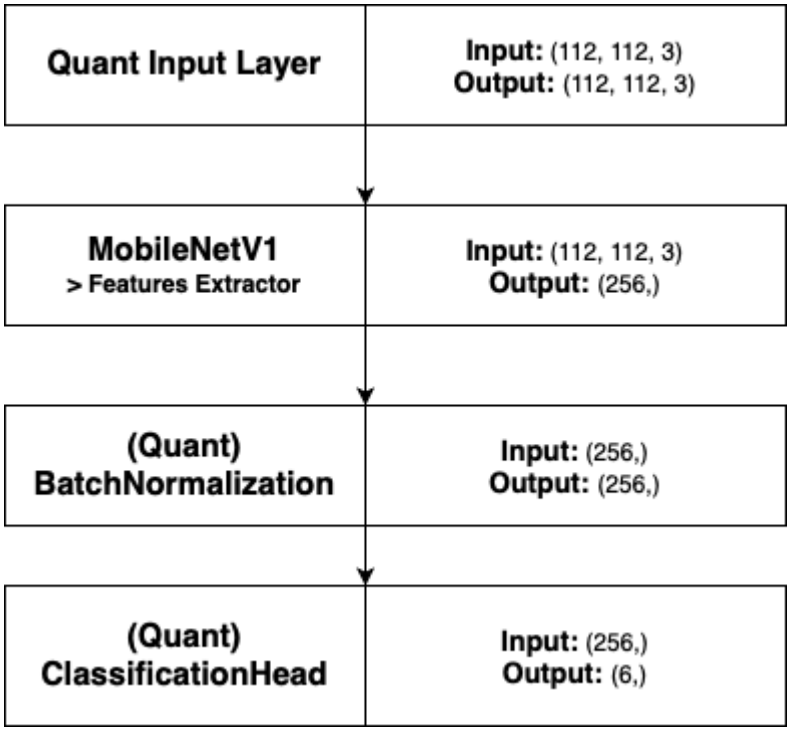
After training the model, we *Quantize* them.

- Dynamic Range (DQR)
- An int with float fallback (Mixed)
- Full-int model (FIQ)

Additionally, we also explored:

- Quantization-Aware Training

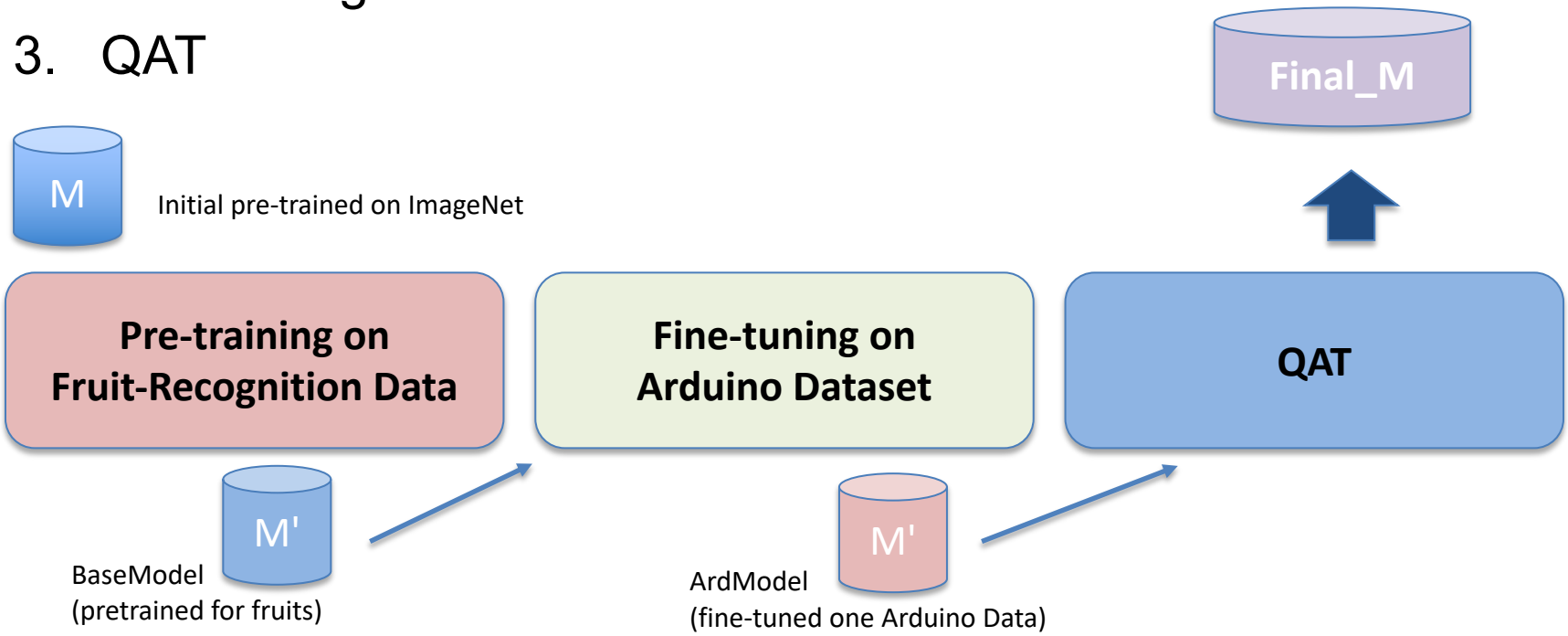
Method	Memory usage	Ralative Speedup
Base Model	2.1MB	x1
Dynamic Range	293KB	x-4.8
Mixed	323KB	x2.4
Full-integer	323KB	x2.1



Training

The training was **divided in three phases**:

1. Pre-training on *Fruit-recognition dataset.*
2. Fine-tuning on *Arduino dataset*
3. QAT

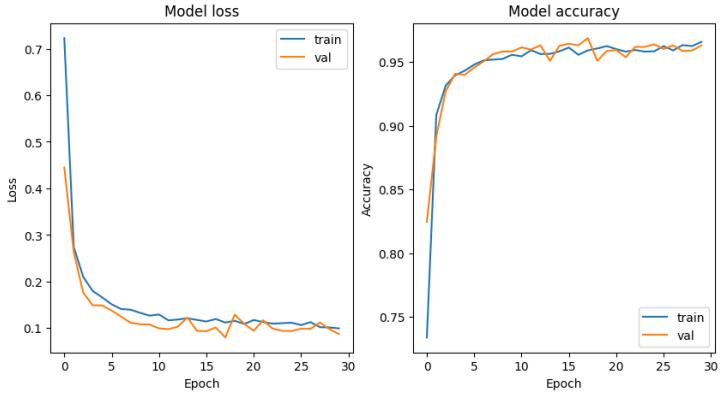


Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

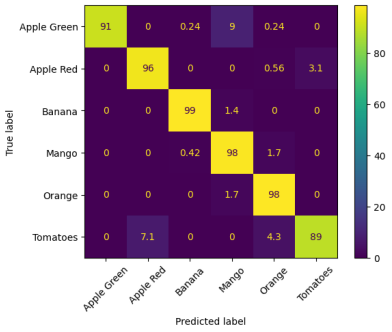
Results: Pre-training

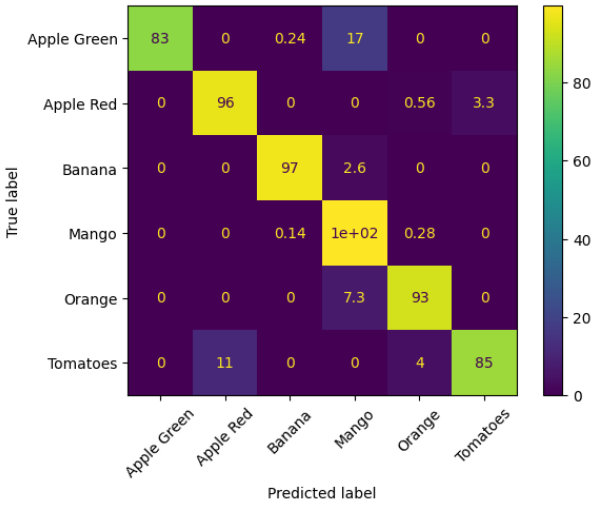
During pre-training the train data was splitted between training and validation.

- Search number of epochs!



Transfer-Learning + Fine-Tuning





Transfer-learning: 18Eps
Fine-tuning: 7Eps

Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

Results: Fine-tuning on Arduino Data

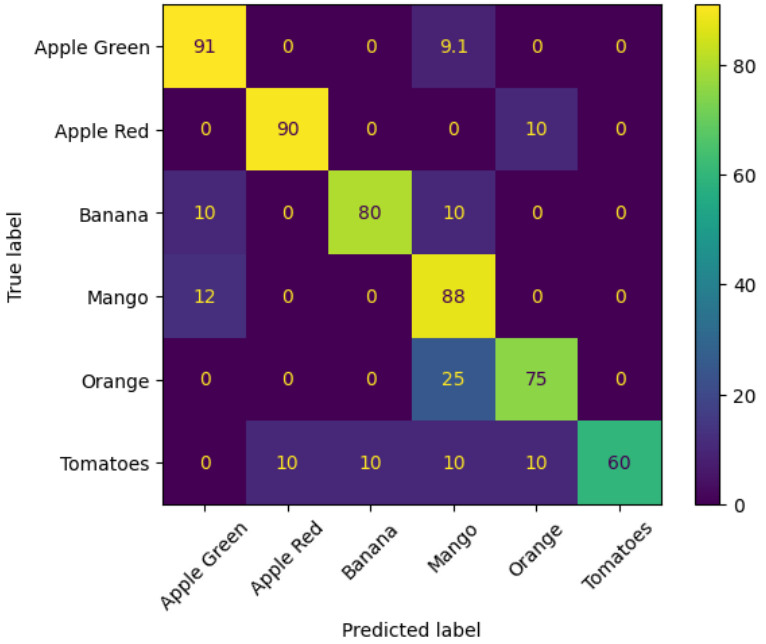
The small dataset, easy to overfit

- **Cross-validation** on the *train* split.
- Final results computed on *test* split.
- Dropout layer during training

Fine-tuning here is used on the CNN backbone!

LR	Weight Decay	Fine-Tuning Epochs	Transfer-Learning Epochs
0.005	0.075	75	15

Model	Accuracy	Macro-F1 Score
Arduino Model	0.853	0.849
DRQ	0.820	0.801
Mixed	0.820	0.821
FIQ	0.803	0.810



Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

POLITECNICO MILANO 1863

Results: QAT

Finally, the trained model is QA-trained.

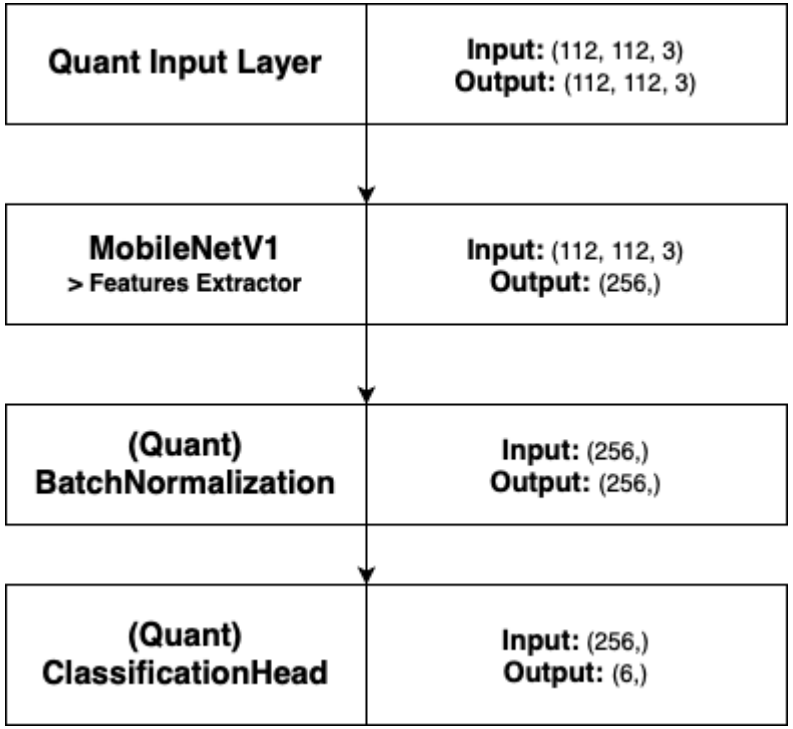
- Very easy to overfit
- Heavy regularisation params.

A lot of tricks to construct the model

- + Big problems

LR	Weight Decay	Training Epochs
1e-4	1.5e-1	16

Model	Accuracy	Macro-F1 Score
QAT Model	0.836	0.814
DRQ	0.836	0.814
Mixed	0.836	0.839
FIQ	0.820	0.829



Daniele Sinigaglia, Vicente Castro
Manuel Roveri | Dipartimento di Elettronica, Informazione e Bioingegneria

POLITECNICO
MILANO 1863

Future Developments

Acknowledgements

Sources

1. what is customer satisfaction [https://asq.org/quality-resources/customer-satisfaction]
2. Eurostat - Infographic: Daily consumption of fruit and vegetables in the EU, 2019
3. How artificial intelligence is redesigning work - Hbr Italia
4. The benefits of sustainability for companies (asvis.it)
5. Sustainable supermarkets: stop plastic and emissions and save food (ilfattoalimentare.it)
6. https://www.statista.com
7. https://www.kantar.com/inspiration/fmcg/2024-wp-record-numbers-hit-the-shops-as-supermarkets-experience-busiest-christmas-since-2019