Bottle, Can or Coffee Cup ?!

Materials MADE SMARTER Centre

sustain future steel manufacturing research hub

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

Discover Materials

04 Improving the Performance for New Objects

This Materials Made Smarter Outreach Demonstration of How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier has been developed by Dr Robert Gibbs with Professor Cinzia Giannetti of Swansea University [↲] for Materials Made Smarter [↲], based upon the NVIDIA DLI "Getting Started with AI on Jetson Nano" course [↲].

This guide describes re-training the model to improve performance on examples of cans, bottles and coffee cups it has not seen before. An accompanying walkthrough video is available at Discover Materials by scanning the QR code or at https://discovermaterials.co.uk/resource/bottle-can-or-coffee-cup/

The video forms part of the section

04 Training for Different Materials

A playlist of all 4 videos is at https://www.youtube.com/playlist?list=PLyl3ubsSP6pUkBdTephBtqL7UfIFfGQ_Z

Also available on the Discover Materials website are a glossary of the highlighted technical terms, an electronic version of the printed booklet and further information about the code, the equipment and progressively more detailed project documentation.

Prifysgol Abertawe Swansea University
Y Gyfadran Gwyddoniaeth a Pheirianneg
Faculty of Science and Engineering
Materials and Manufacturing Research Institute

UKRI Engineering and Physical Sciences Research Council

NVIDIA. DEEP LEARNING INSTITUTE

developed by Dr R. Gibbs and Prof. C. Giannetti for Materials Made Smarter,
based upon the NVIDIA DLI
"Getting Started with AI on Jetson Nano" course.
C.G. would like to acknowledge the support of the EPSRC (EP/V061798/1).

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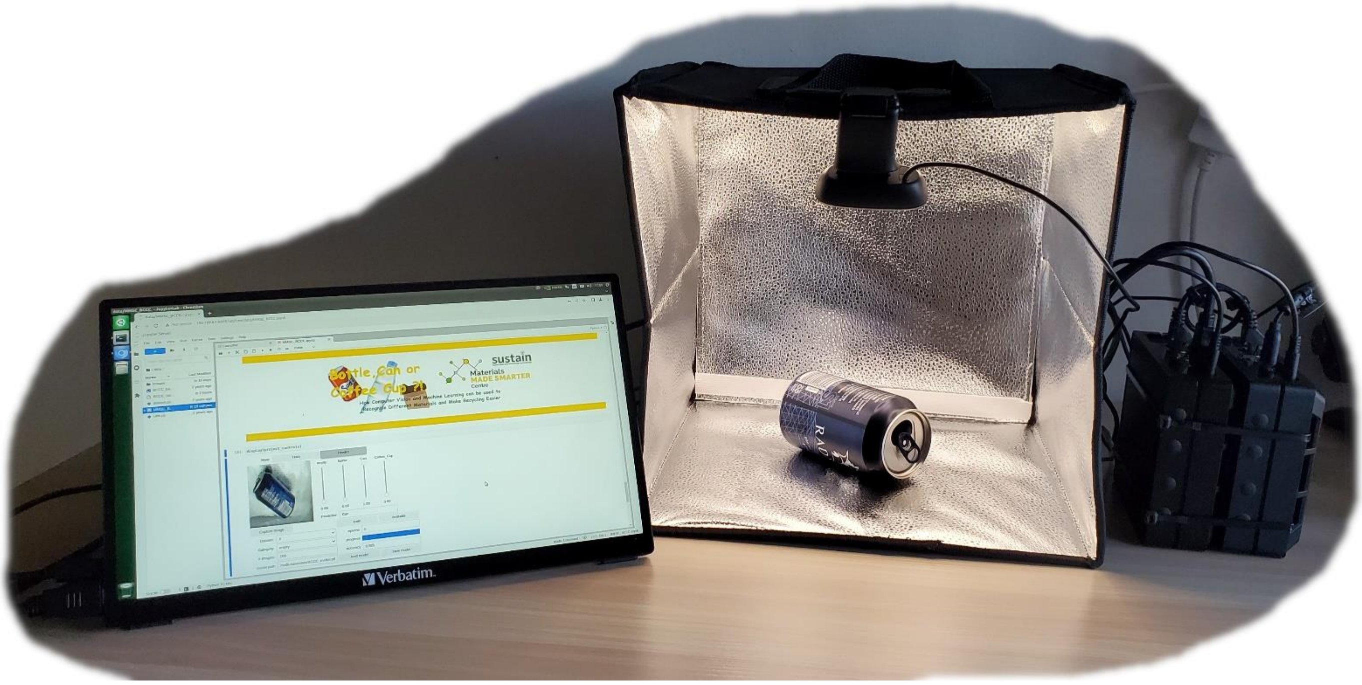
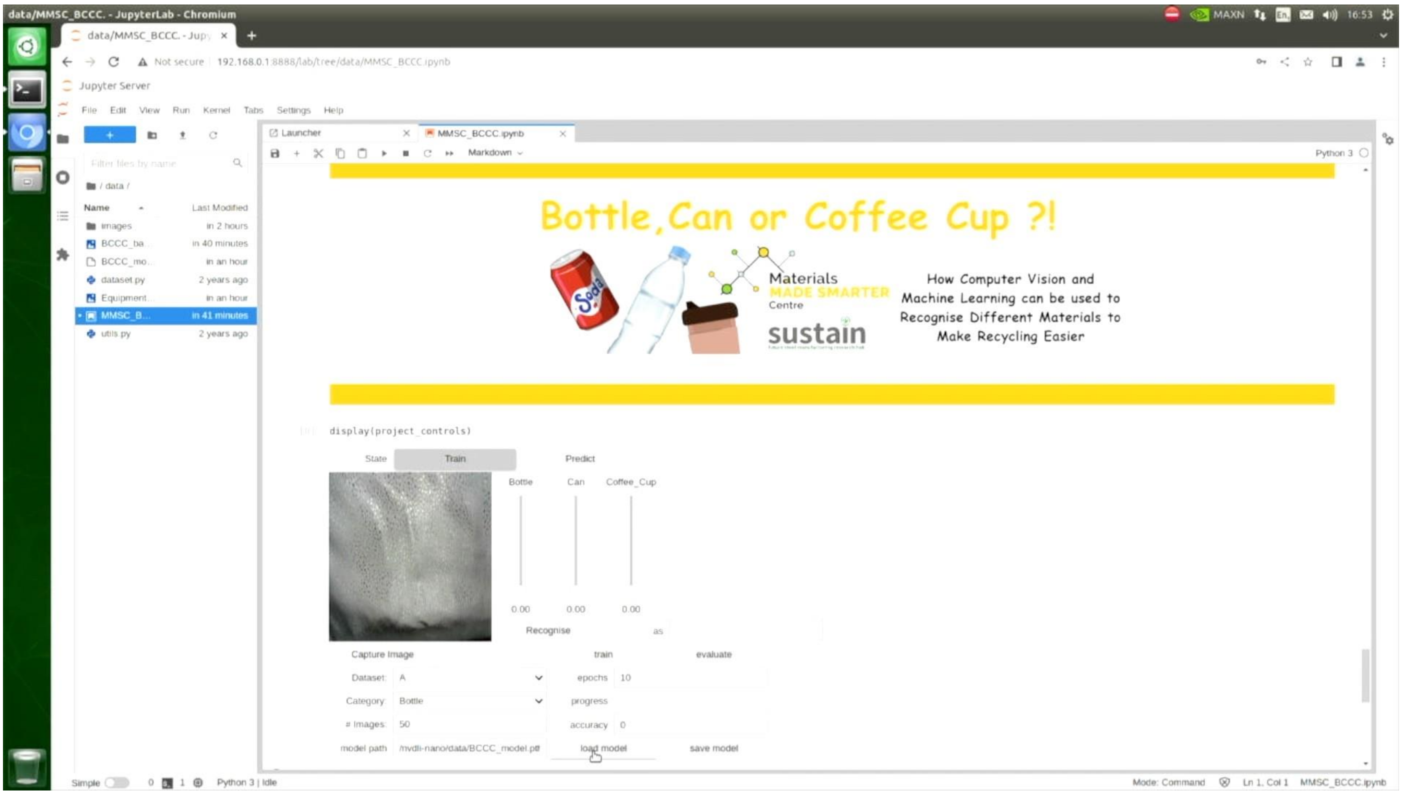
https://discovermaterials.co.uk
and learn more about what's happening in the world of materials science!

It is assumed that you have the system up and running according to the guide 01 Getting the System Up and Running available on the website.





Bottle,Can or Coffee Cup ?!

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
display(project_controls)
```

Dataset: A

Category: Bottle

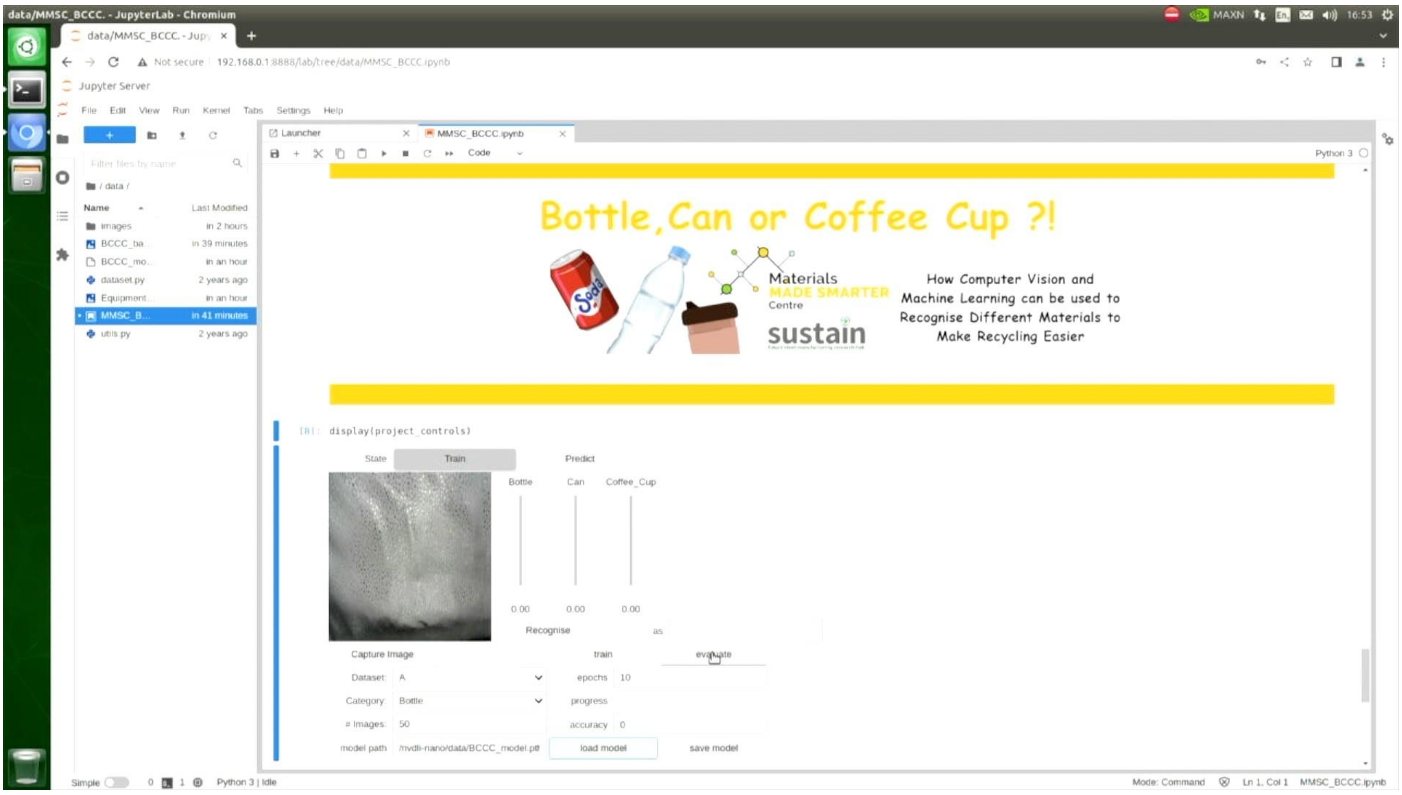
Images: 50

model path: /nvdli-nano/data/BCCC_model.pth

epochs: 10

accuracy: 0

We've previously saved our trained model (see the guide 02 How to Use the Project Controls to Identify Objects, available on the website, for the process of training the model) so we don't need to re-run our training. We can press **load model** to load in our saved model.


data/MMSC_BCCC. - JupyterLab - Chromium
MAXN
16:53
data/MMSC_BCCC. - Jupy
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Code
Python 3
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Capture Image
Recognise
evaluate
load model
save model
Simple
Mode: Command
Ln 1, Col 1
MMSC_BCCC.ipynb

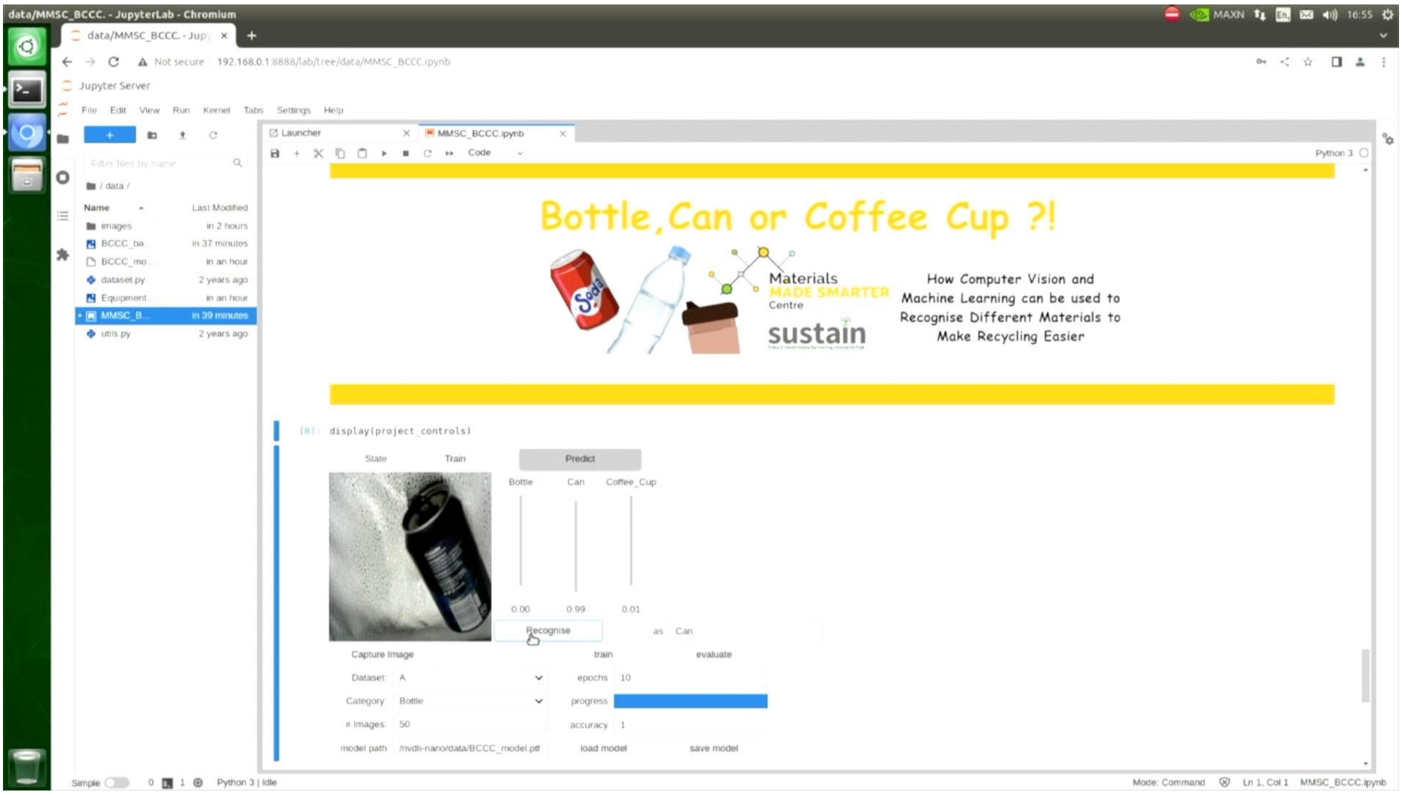
Name	Last Modified
images	in 2 hours
BCCC_ba...	in 39 minutes
BCCC_mo...	in an hour
dataset.py	2 years ago
Equipment...	in an hour
MMSC_B...	in 41 minutes
utils.py	2 years ago

```
[8]: display(project_controls)
```

Bottle 0.00 Can 0.00 Coffee_Cup 0.00

Dataset: A
Category: Bottle
Images: 50
model path: mvdli-nano/data/BCCC_model.pth
epochs: 10
progress
accuracy: 0

Instead of training we **evaluate** the model that we've just loaded in, This still takes approximately 60 seconds because it still has to load in the ResNet 18 model and replace the final layer of that model but it is much faster than the 4.6 minutes it takes to train from scratch with our existing training dataset.


data/MMSC_BCCC. - JupyterLab - Chromium
MAXN
16:55
data/MMSC_BCCC. - Jupy
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Code
Python 3
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Capture Image
Recognise
train
evaluate
load model
save model
Simple
Mode: Command
Ln 1, Col 1
MMSC_BCCC.ipynb

Name	Last Modified
images	in 2 hours
BCCC_ba...	in 37 minutes
BCCC_mo...	in an hour
dataset.py	2 years ago
Equipment...	in an hour
MMSC_B...	in 39 minutes
utils.py	2 years ago

```
[8]: display(project_controls)
```

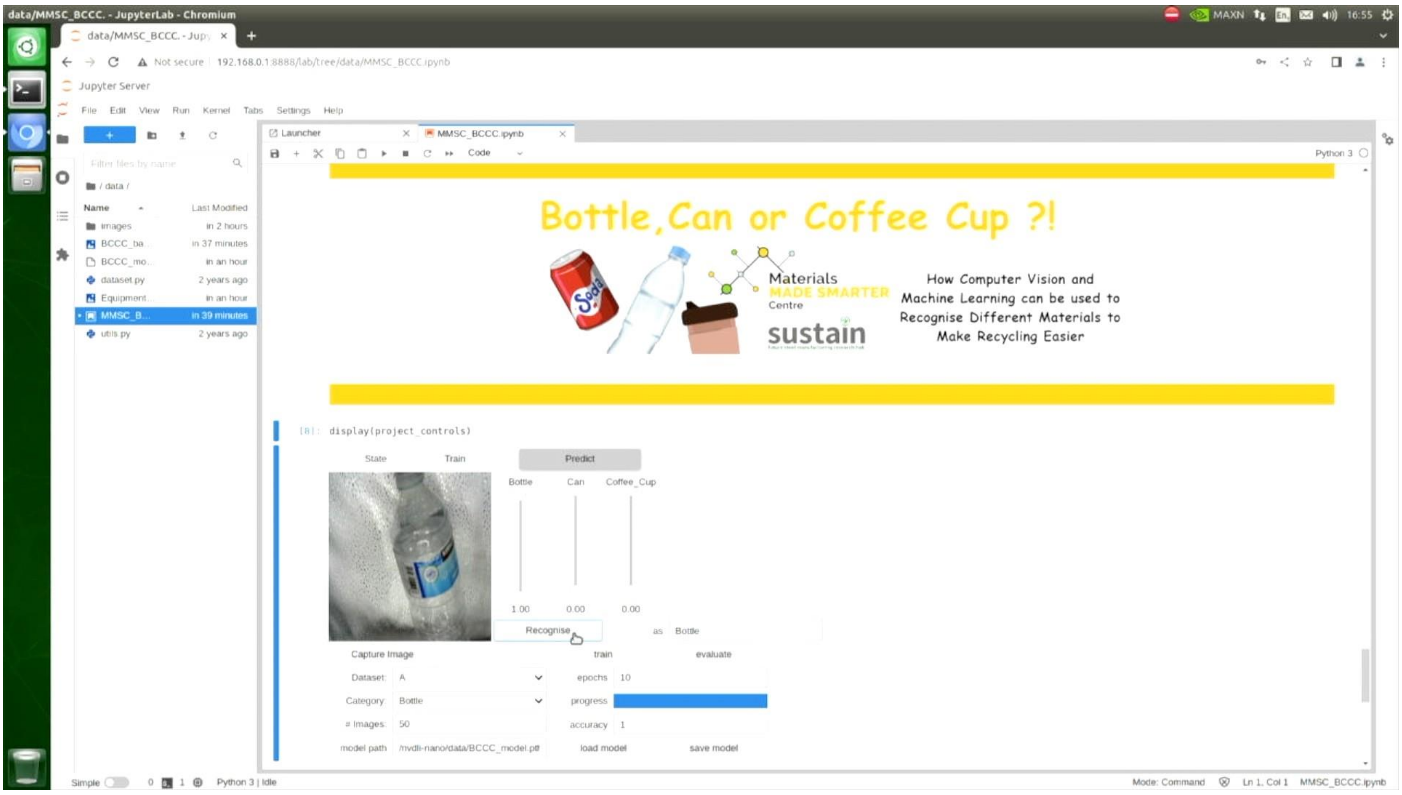
Bottle 0.00 Can 0.99 Coffee_Cup 0.01

Recognise as Can

Dataset: A
Category: Bottle
Images: 50
model path: mvdli-nano/data/BCCC_model.pth
epochs: 10
progress
accuracy: 1

The system again switches to the predict mode, ready to recognize the objects you put in

It recognises the can with 99% confidence.


data/MMSC_BCCC. - JupyterLab - Chromium
MAXN 16:55
data/MMSC_BCCC. - Jupy
Not secure 192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Code
Python 3
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
Simple 0 1 Python 3 | Idle
Mode: Command Ln 1, Col 1 MMSC_BCCC.ipynb

Name	Last Modified
images	in 2 hours
BCCC_ba...	in 37 minutes
BCCC_mo...	in an hour
dataset.py	2 years ago
Equipment...	in an hour
MMSC_B...	in 39 minutes
utils.py	2 years ago

```
[8]: display(project_controls)
```

State Train Predict

Bottle	Can	Coffee_Cup
1.00	0.00	0.00

Recognise as Bottle

Capture Image train evaluate

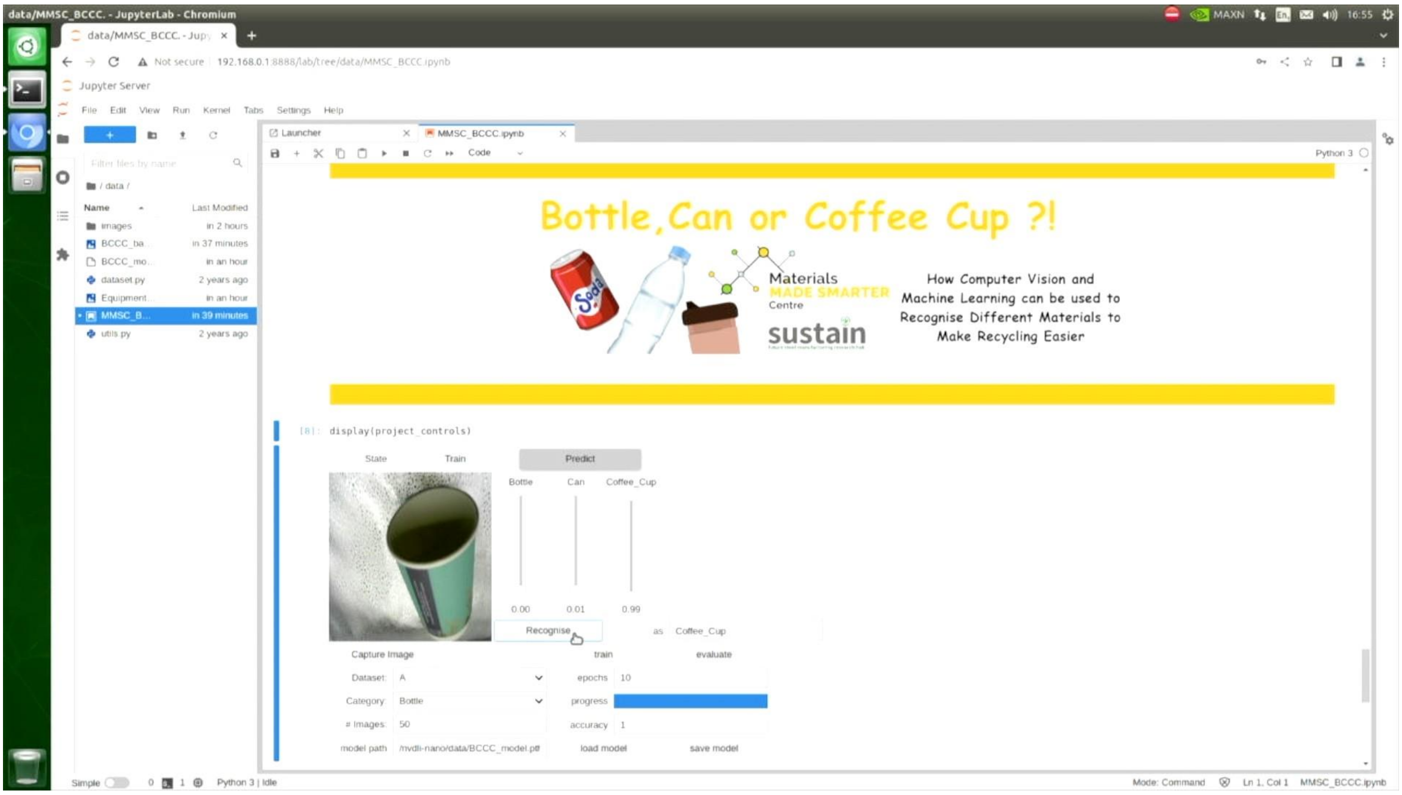
Dataset: A epochs 10

Category: Bottle progress

# Images: 50 accuracy 1

model path /nvdli-nano/data/BCCC_model.pth load model save model

It recognizes the bottle with 100% confidence


data/MMSC_BCCC. - JupyterLab - Chromium
MAXN 16:55
data/MMSC_BCCC. - Jupy
Not secure 192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Code
Python 3
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
Simple 0 1 Python 3 | Idle
Mode: Command Ln 1, Col 1 MMSC_BCCC.ipynb

Name	Last Modified
images	in 2 hours
BCCC_ba...	in 37 minutes
BCCC_mo...	in an hour
dataset.py	2 years ago
Equipment...	in an hour
MMSC_B...	in 39 minutes
utils.py	2 years ago

```
[8]: display(project_controls)
```

State Train Predict

Bottle	Can	Coffee_Cup
0.00	0.01	0.99

Recognise as Coffee_Cup

Capture Image train evaluate

Dataset: A epochs 10

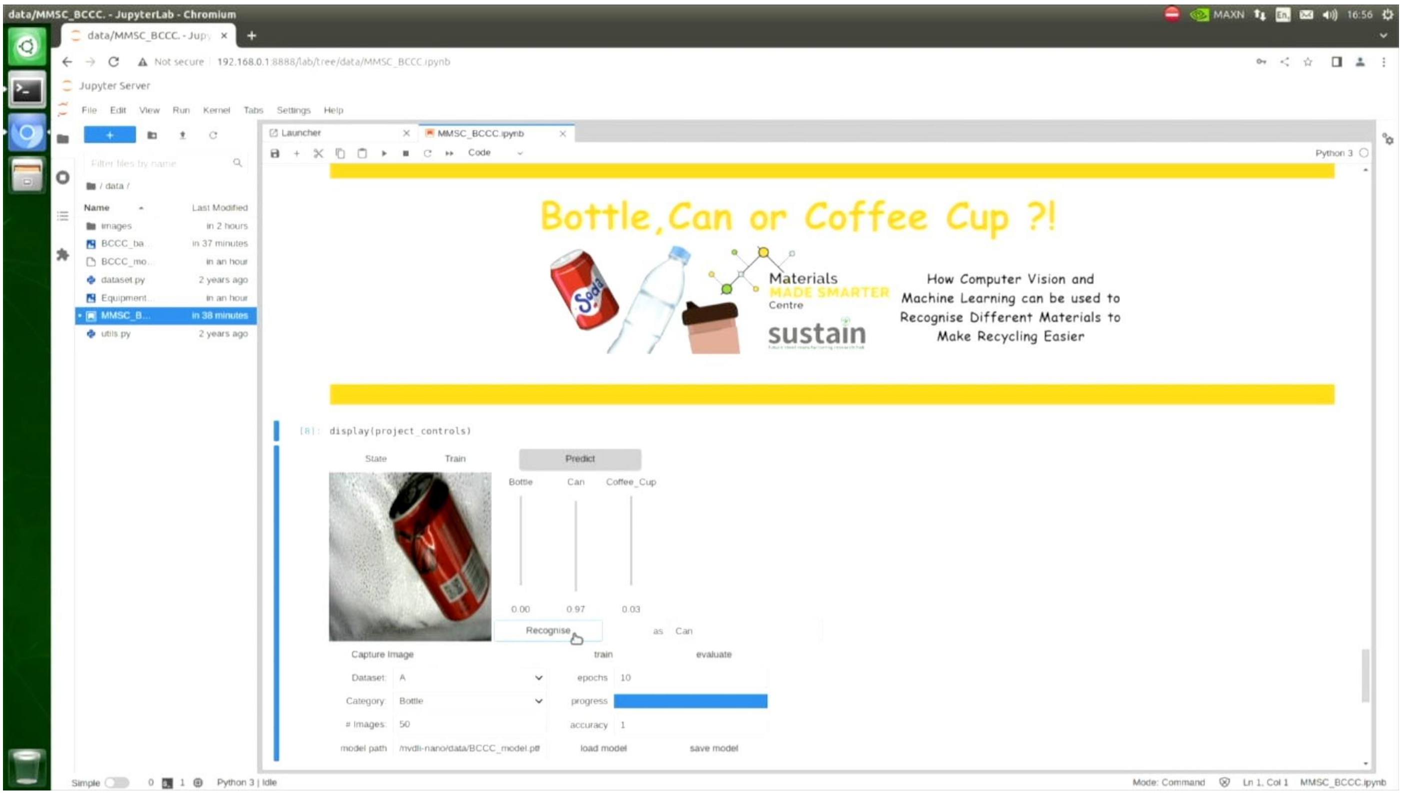
Category: Bottle progress

# Images: 50 accuracy 1

model path /nvdli-nano/data/BCCC_model.pth load model save model

and also the coffee cup it has been trained on with 99% confidence.

Thumbnails of the original training dataset of 50 images of these three objects, stored in **BCCC_A** are attached to the end of this guide.

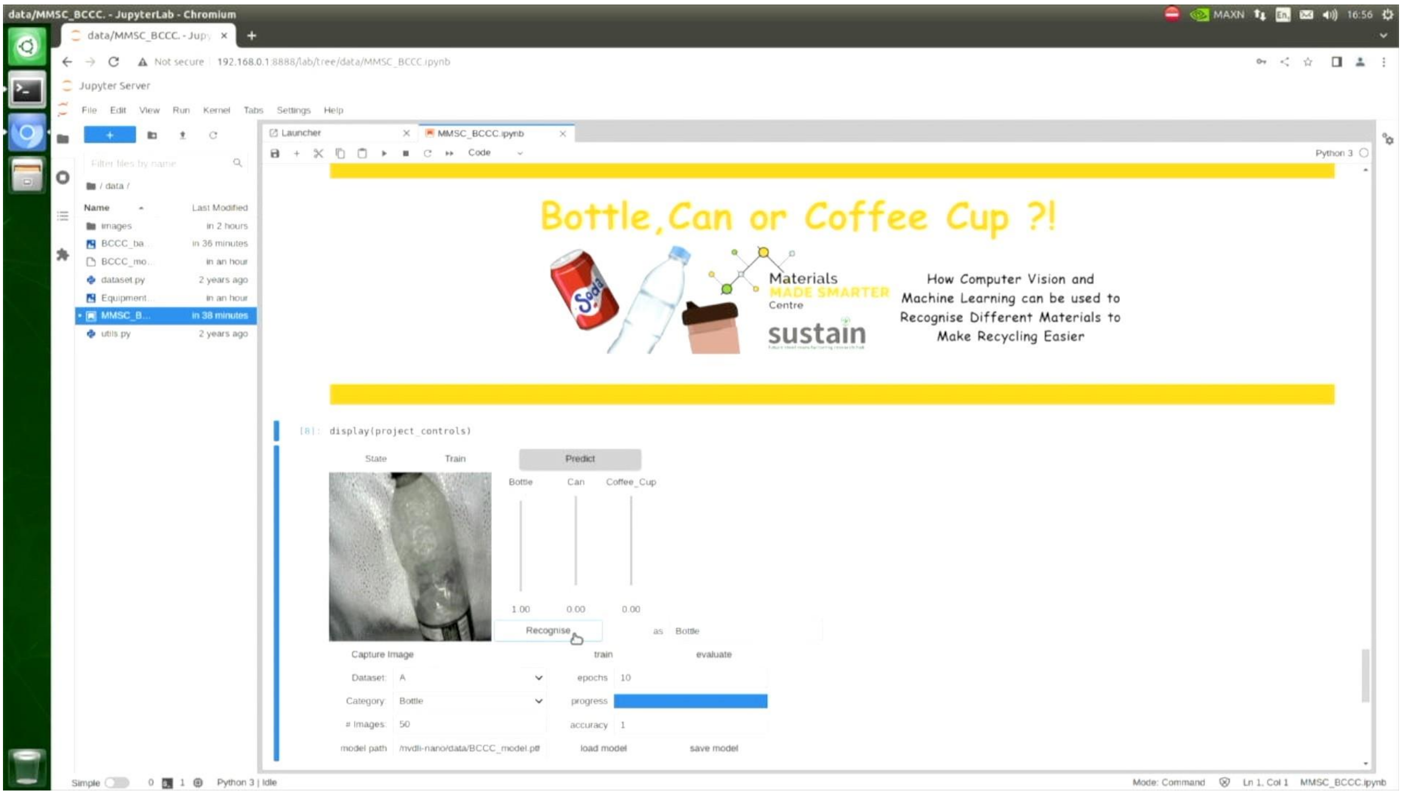

data/MMSC_BCCC. - JupyterLab - Chromium
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Recognise
Capture Image
train
evaluate
load model
save model

```
[8]: display(project_controls)
```

Bottle 0.00, Can 0.97, Coffee_Cup 0.03 — as Can

Dataset: A
Category: Bottle
Images: 50
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 10
accuracy: 1

If we experiment with putting a can that the system hasn't seen before it successfully recognizes another can. There something common to both cans, even though they have different colors. The system has only 97% confidence, but that still very confident.


data/MMSC_BCCC. - JupyterLab - Chromium
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Recognise
Capture Image
train
evaluate
load model
save model

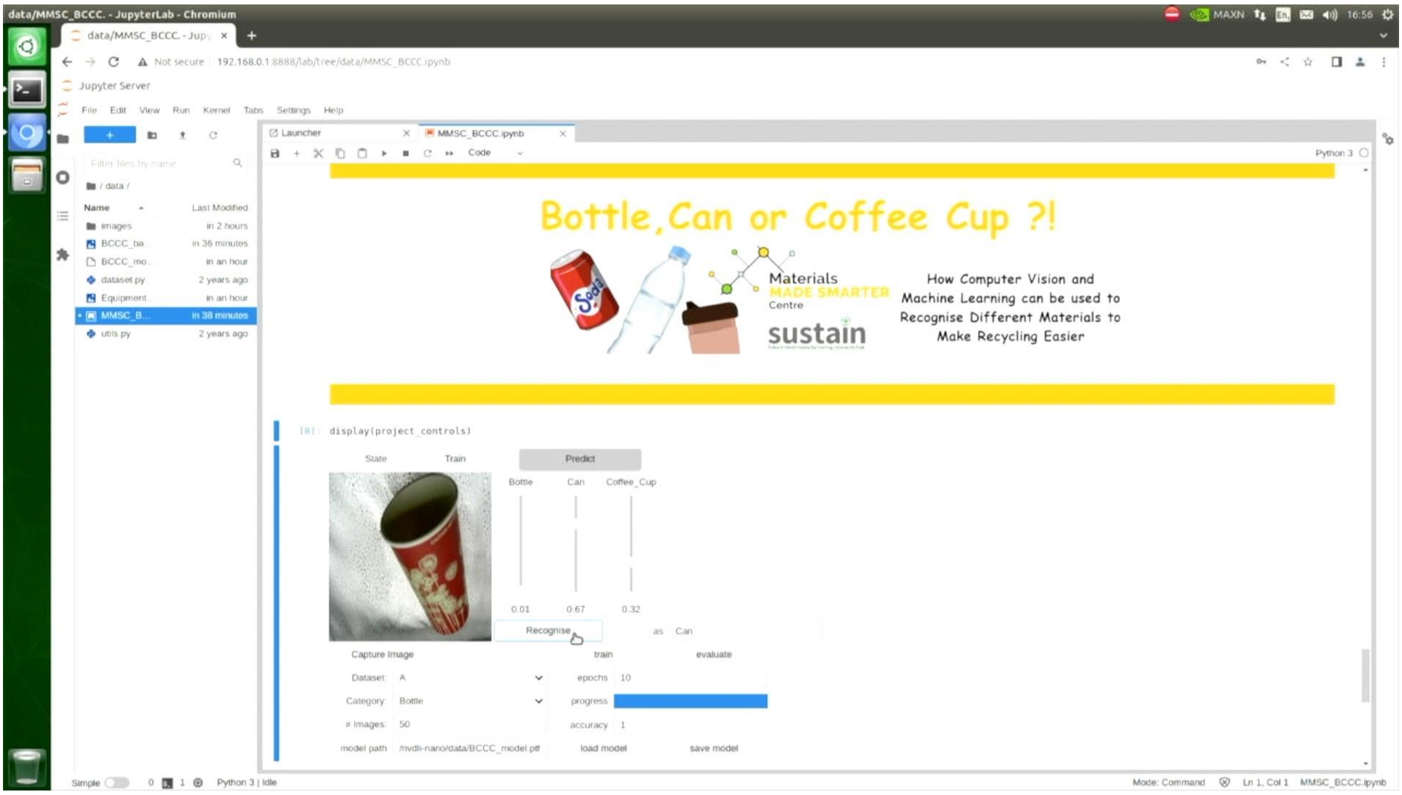
```
[8]: display(project_controls)
```

Bottle 1.00, Can 0.00, Coffee_Cup 0.00 — as Bottle

Dataset: A
Category: Bottle
Images: 50
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 10
accuracy: 1

A bottle it hasn't been trained on can be identified with 100% confidence.

The system has a good understanding of the features of a bottle. What do you think is common in bottles with is different to the other three objects that they are easy to recognize?


Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Recognise
Capture Image
train
evaluate
load model
save model

```
[8]: display(project_controls)
```

Bottle	Can	Coffee_Cup
0.01	0.67	0.32

as Can

Dataset: A

Category: Bottle

Images: 50

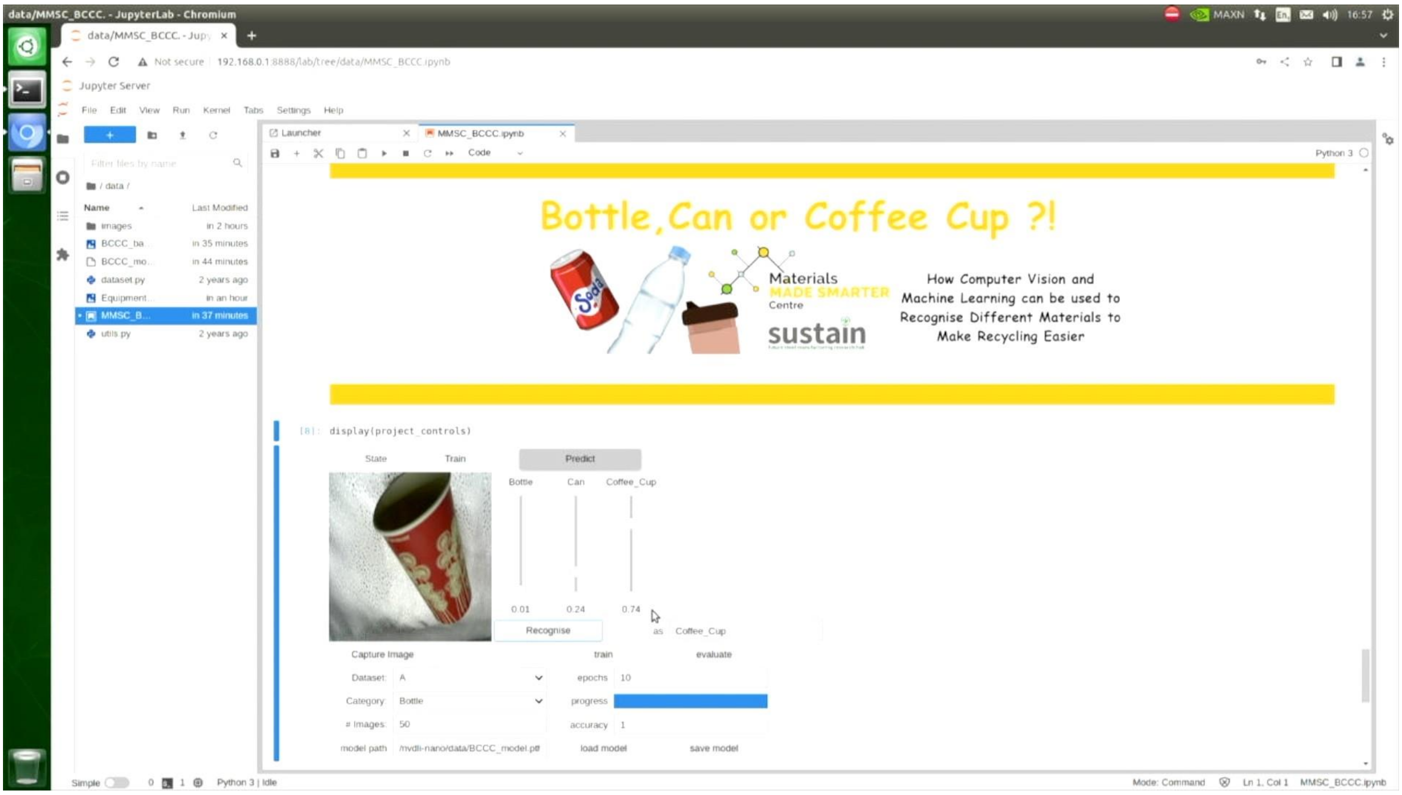
model path /nvdli-nano/data/BCCC_model.pth

epochs 10

accuracy 1

Now if we try a coffee cup that is different to the one it has been trained on the system is confused about what the object is

There must be something in the coffee cup that it has been trained on, that it recognizes happily, that isn't in the new coffee cup.



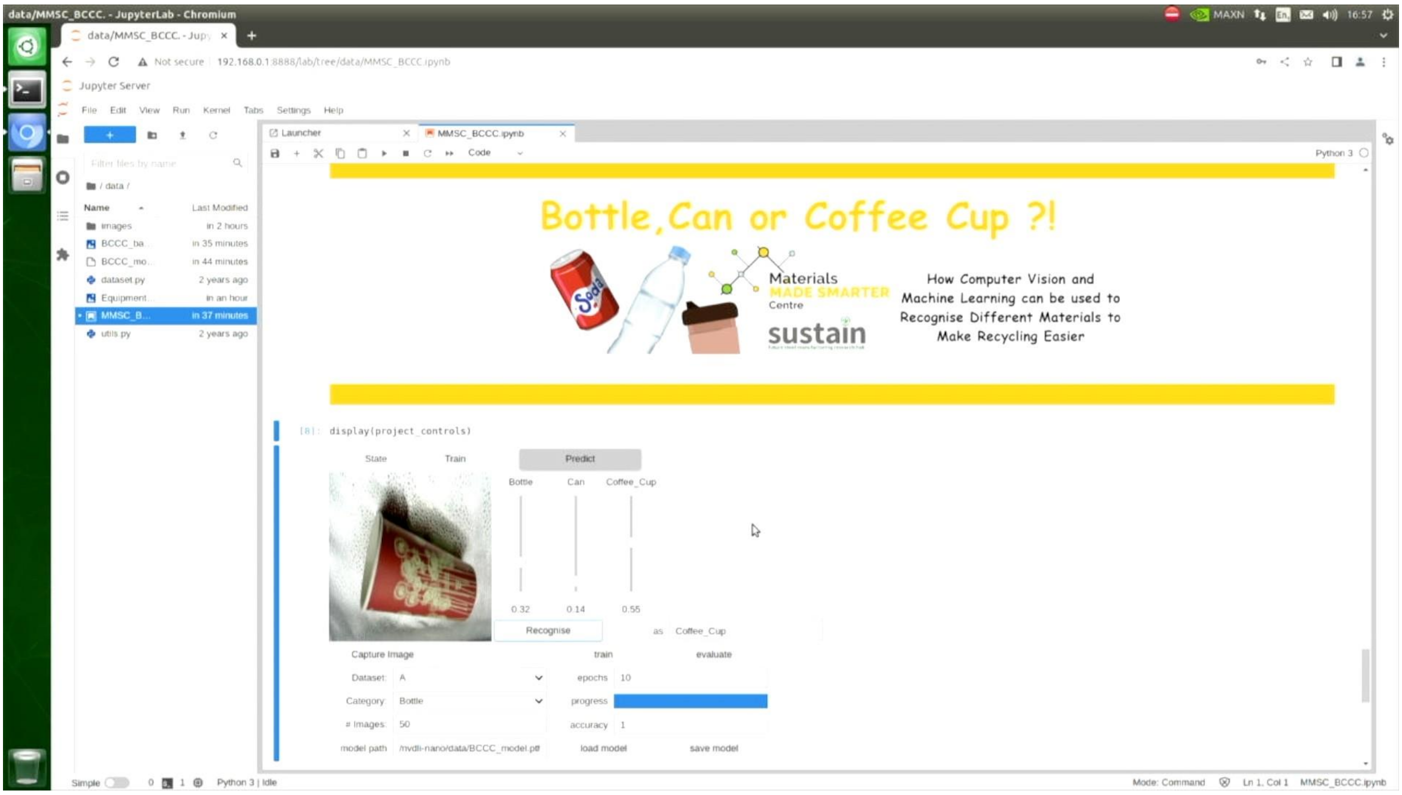
data/MMSC_BCCC. - JupyterLab - Chromium
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Bottle, Can or Coffee Cup ?!
Materials
MADE SMARTER
Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Recognise
Capture Image
train
evaluate
load model
save model
Mode: Command
Ln 1, Col 1
MMSC_BCCC.ipynb

```
[8]: display(project_controls)
```

Bottle	Can	Coffee_Cup
0.01	0.24	0.74

as Coffee_Cup

Dataset: A
Category: Bottle
Images: 50
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 10
accuracy: 1



data/MMSC_BCCC. - JupyterLab - Chromium
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Bottle, Can or Coffee Cup ?!
Materials
MADE SMARTER
Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Recognise
Capture Image
train
evaluate
load model
save model
Mode: Command
Ln 1, Col 1
MMSC_BCCC.ipynb

```
[8]: display(project_controls)
```

Bottle	Can	Coffee_Cup
0.32	0.14	0.55

as Coffee_Cup

Dataset: A
Category: Bottle
Images: 50
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 10
accuracy: 1

Sometimes the system does identify the coffee cup. But only with 74% or 55% confidence

This coffee cup is a new coffee cup it hasn't seen before and it can easily be confused.

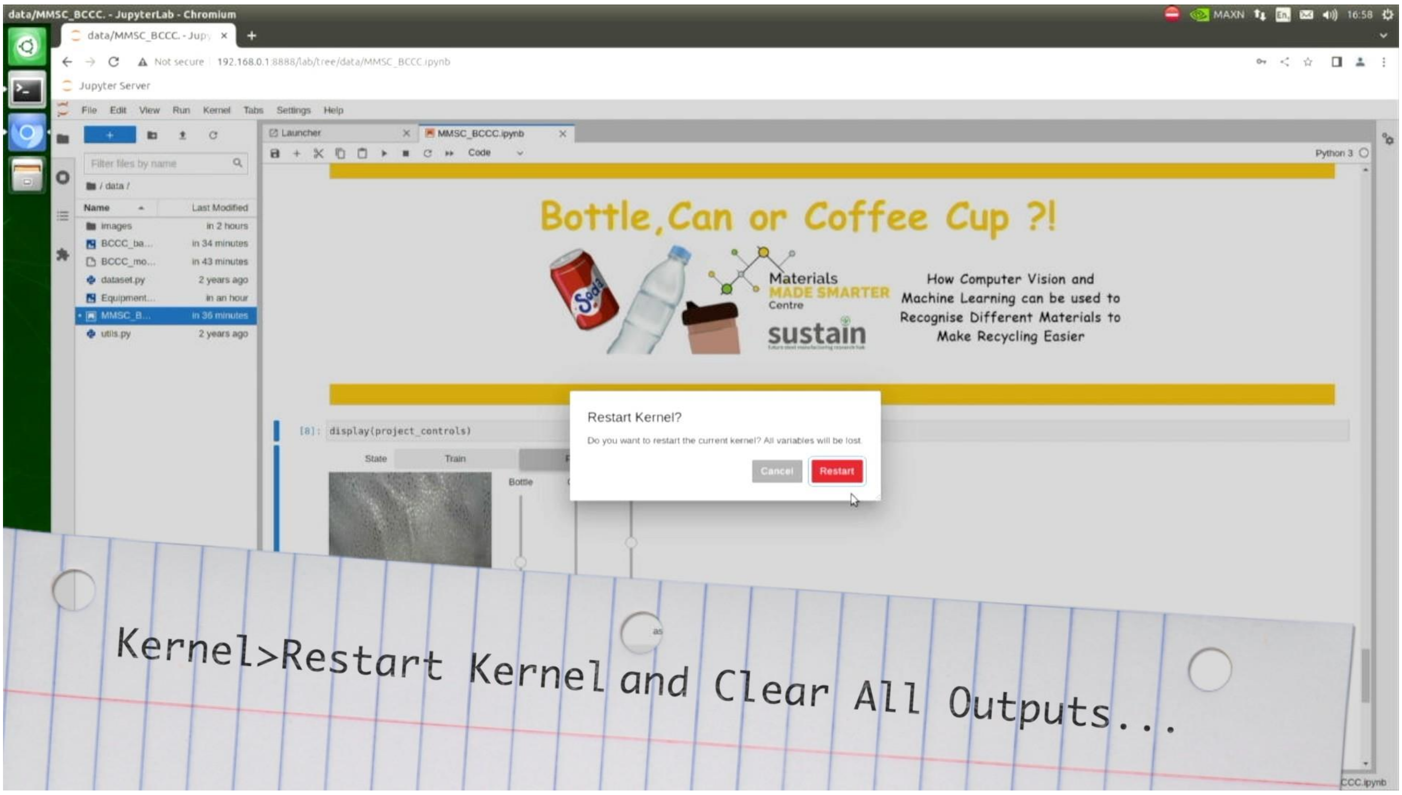
So how can we improve the situation on objects it hasn't seen before?

The key is giving it some more training images on the new versions of the objects so it can get a more general impression of what a coffee cup is, and be less confused.

What we want to do is just give it a few extra images of what a coffee cup looks like, and maybe also what the new can and the bottle looks like, but we don't want to damage our original data sets?

We want to keep **BCCC_A** intact but we don't want to have to repeat the capture of the 50 images we have already obtained.

We are going to use the terminal to make an alternative copy of the original dataset, **BCCC_B**, which we can add more images to.


data/MMSC_BCCC. - JupyterLab - Chromium
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Python 3
Name
Last Modified
images
in 2 hours
BCCC_ba...
in 34 minutes
BCCC_mo...
in 43 minutes
dataset.py
2 years ago
Equipment...
in an hour
MMSC_B...
in 36 minutes
utils.py
2 years ago
Bottle,Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Bottle

```
[8]: display(project_controls)
```

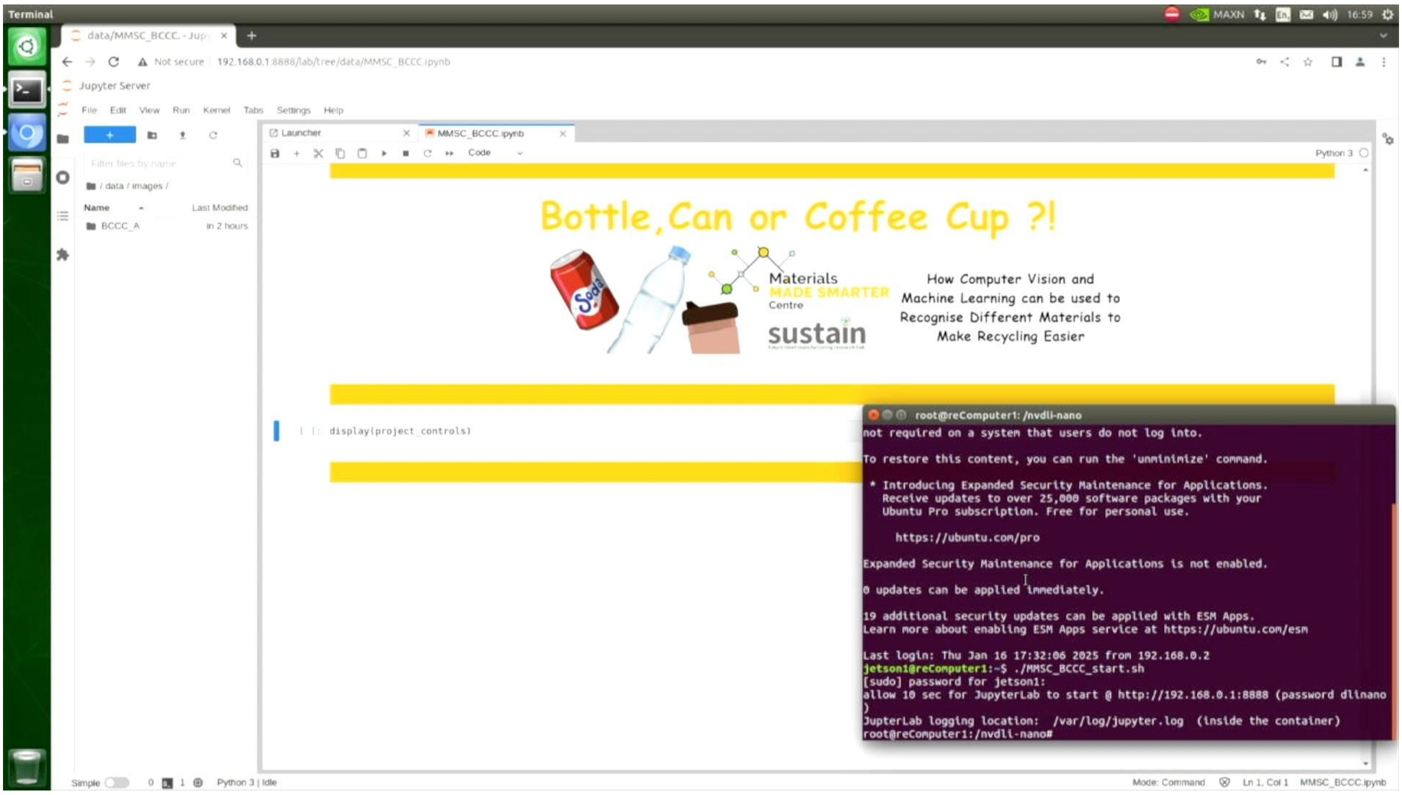
Restart Kernel?

Do you want to restart the current kernel? All variables will be lost.

Cancel Restart

Kernel>Restart Kernel and Clear All Outputs...

We need to stop the system from running so we go to **Kernel>Restart Kernel and Clear All Outputs…** and click on **Restart** when it appears.



Bottle, Can or Coffee Cup ?!

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[ ]: display(project_controls)
```

```
root@reComputer1: /nvdli-nano
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.

 * Introducing Expanded Security Maintenance for Applications.
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   Ubuntu Pro subscription. Free for personal use.

     https://ubuntu.com/pro

Expanded Security Maintenance for Applications is not enabled.

0 updates can be applied immediately.

19 additional security updates can be applied with ESM Apps.
Learn more about enabling ESM Apps service at https://ubuntu.com/esm

Last login: Thu Jan 16 17:32:06 2025 from 192.168.0.2
jetson1@reComputer1:~$ ./MMSC_BCCC_start.sh
[sudo] password for jetson1:
allow 10 sec for JupyterLab to start @ http://192.168.0.1:8888 (password dlinano
)
JupterLab logging location:  /var/log/jupyter.log  (inside the container)
root@reComputer1:/nvdli-nano#
```
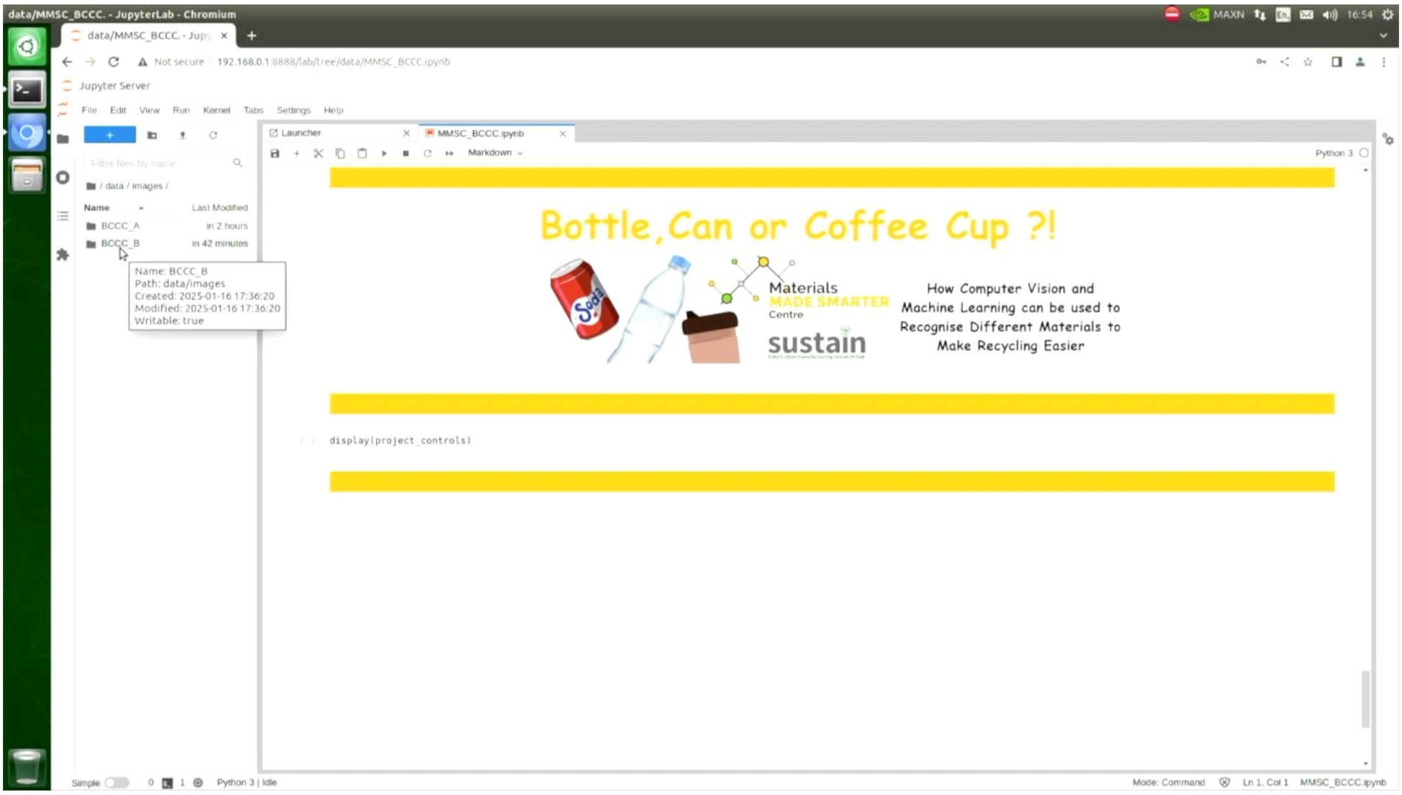

We click onto the terminal

In the terminal we will use the following commands in order to copy the existing BCCC_A folder into a new BCCC_B folder, pressing return after each step.

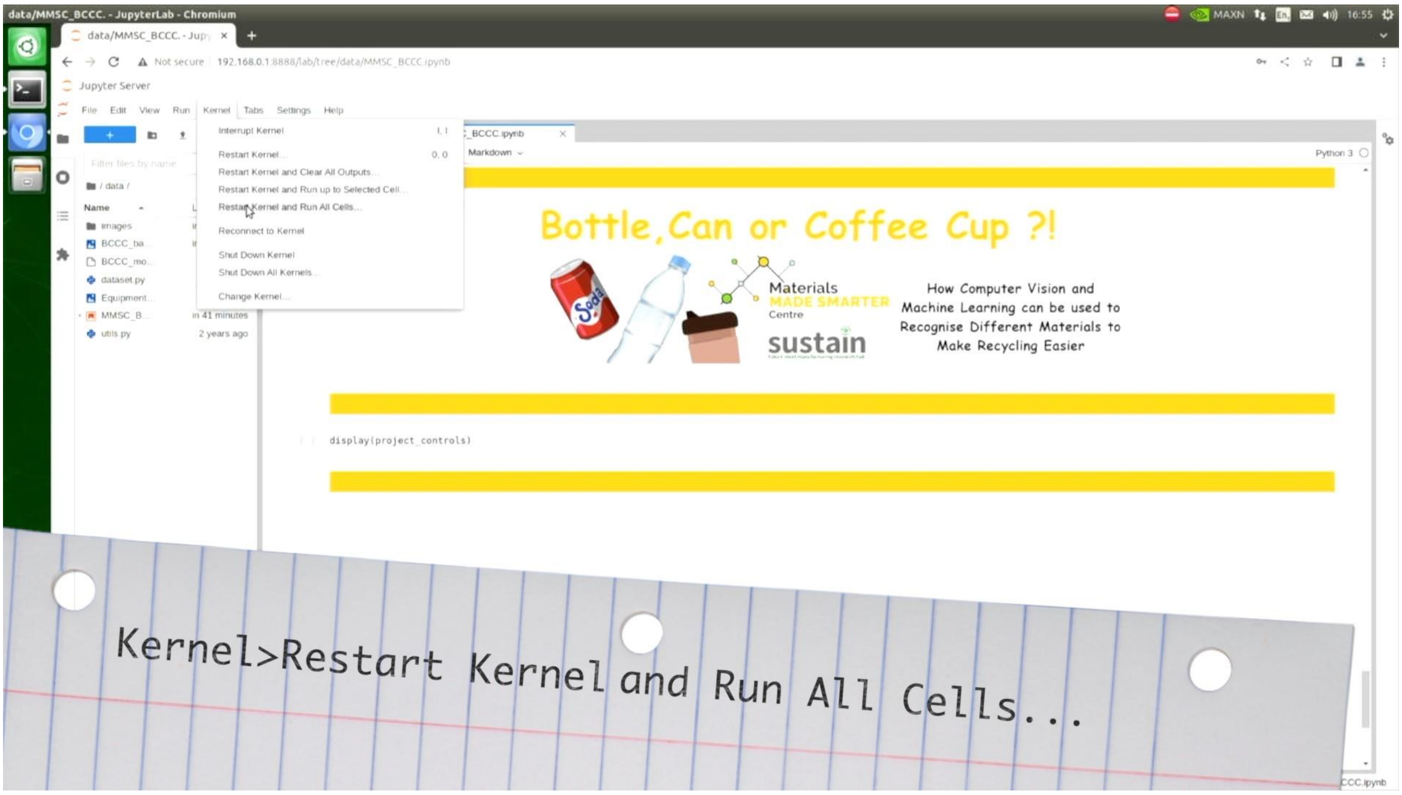
```
root@reComputer1:/nvdli-nano# ls
root@reComputer1:/nvdli-nano# cd data
root@reComputer1:/nvdli-nano# ls
root@reComputer1:/nvdli-nano# cd images
root@reComputer1:/nvdli-nano# ls
root@reComputer1:/nvdli-nano# cp -r ./BCCC_A/ ./BCCC_B/
root@reComputer1:/nvdli-nano# ls
```


data/MMSC_BCCC. - JupyterLab - Chromium
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
/ data / images /
Name Last Modified
BCCC_A in 2 hours
BCCC_B in 42 minutes
Launcher
MMSC_BCCC.ipynb
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
Mode: Command
Ln 1, Col 1
MMSC_BCCC.ipynb

Name: BCCC_B
Path: data/images
Created: 2025-01-16 17:36:20
Modified: 2025-01-16 17:36:20
Writable: true

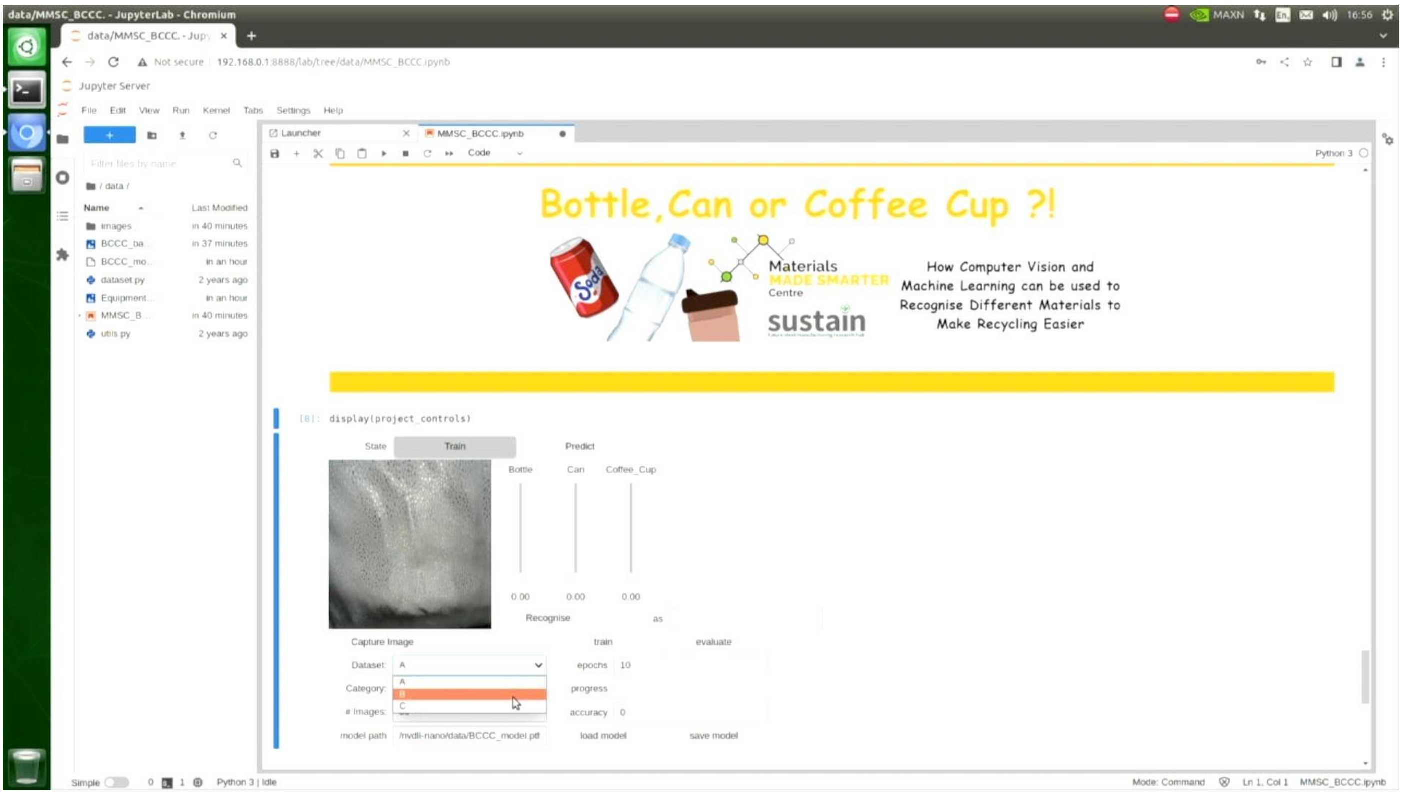
```
display(project_controls)
```

and then we can return to the Jupyter Notebook in the chromium browser and see that our replicated BCCC_B dataset is present, already populated with 50 images of the original objects.


data/MMSC_BCCC. - JupyterLab - Chromium
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Interrupt Kernel
Restart Kernel...
Restart Kernel and Clear All Outputs...
Restart Kernel and Run up to Selected Cell...
Restart Kernel and Run All Cells...
Reconnect to Kernel
Shut Down Kernel
Shut Down All Kernels...
Change Kernel...
/ data /
images
BCCC_ba
BCCC_mo
dataset.py
Equipment
MMSC_B
utils.py
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
Kernel>Restart Kernel and Run All Cells...

```
display(project_controls)
```

We go to **Kernel>Restart Kernel and Run All Cells…** and click on **Restart** when it appears to restart the system. Wait for 50 seconds.



```
display(project_controls)
```

Dataset: A

Category:

epochs 10

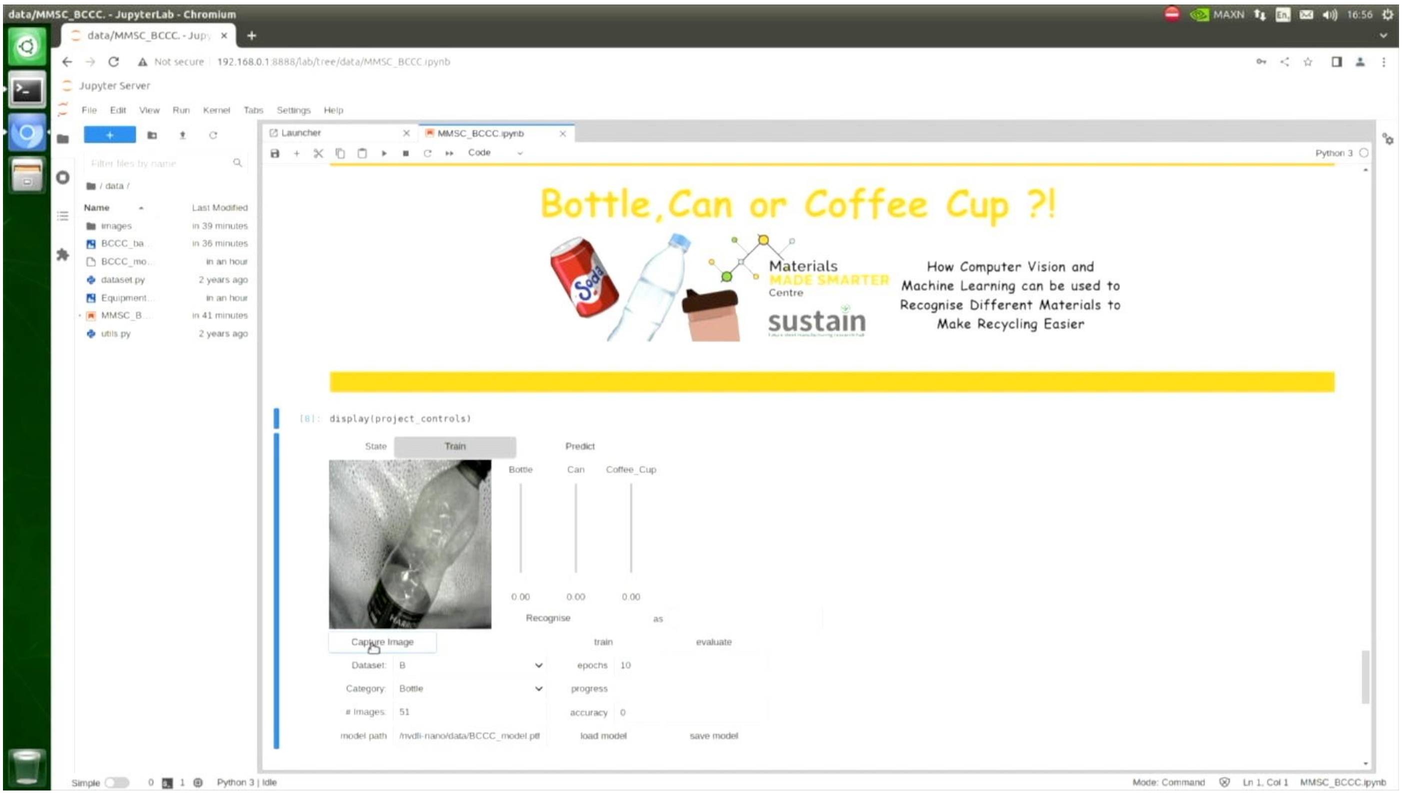
accuracy 0

model path /nvdli-nano/data/BCCC_model.pth

Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Bottle
Can
Coffee_Cup
0.00
0.00
0.00
Recognise
as
Capture Image
train
evaluate
A
B
C
# Images:
progress
load model
save model

We are in training mode again and we need to select our new dataset B. We can see that there are already 50 images in each of the categories of that dataset as well.

We are going to add images of the three new examples of each object. It will only need ten images of each to improve the system.



```
display(project_controls)
```

Dataset: B

Category: Bottle

Images: 51

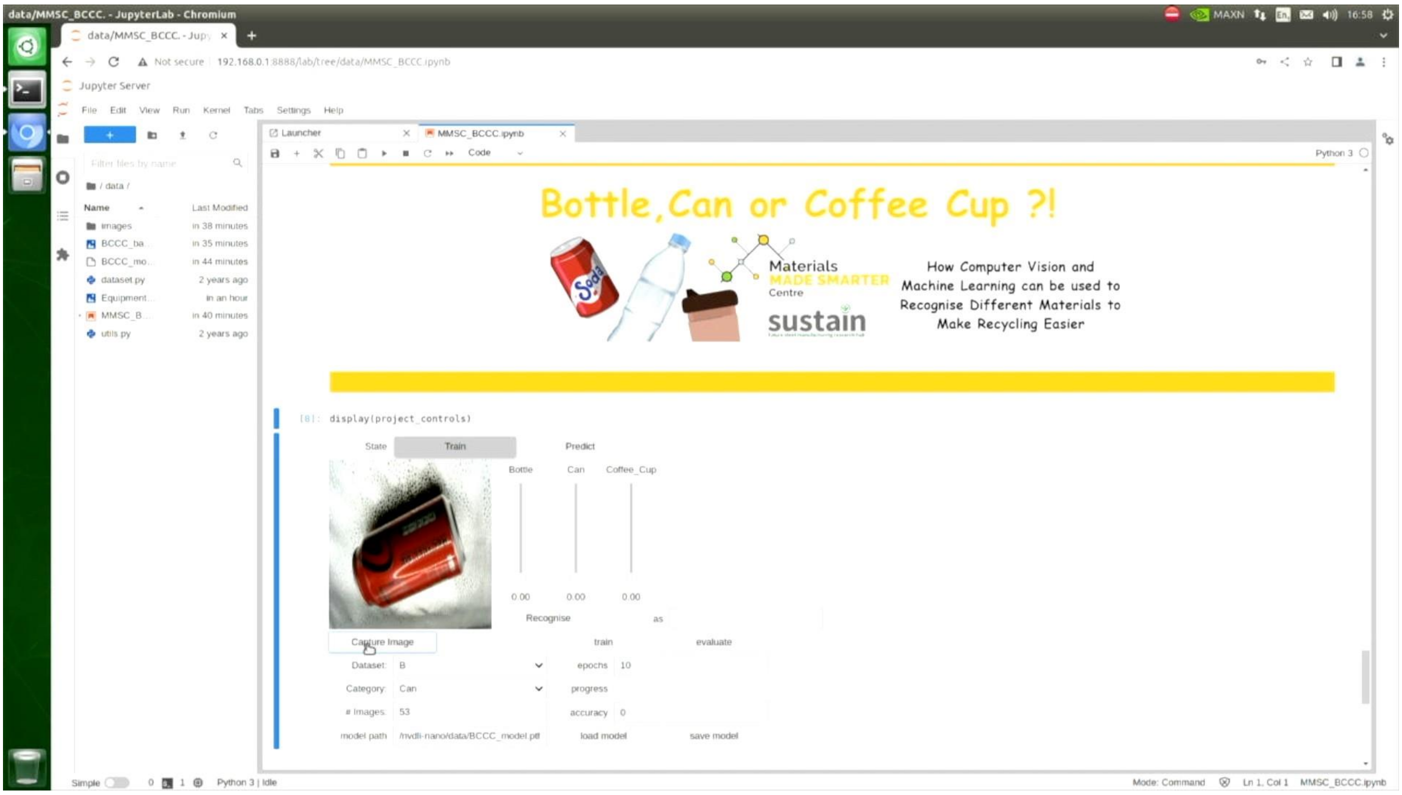
epochs 10

accuracy 0

model path /nvdli-nano/data/BCCC_model.pth

Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Bottle
Can
Coffee_Cup
0.00
0.00
0.00
Recognise
as
Capture Image
train
evaluate
progress
load model
save model

We place the new bottle in the system, click **Capture Image**, and then move the bottle to a different orientation and repeat 10 times.



Bottle,Can or Coffee Cup ?!

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[8]: display(project_controls)
```

State: Train

Predict: Bottle 0.00, Can 0.00, Coffee_Cup 0.00

Dataset: B

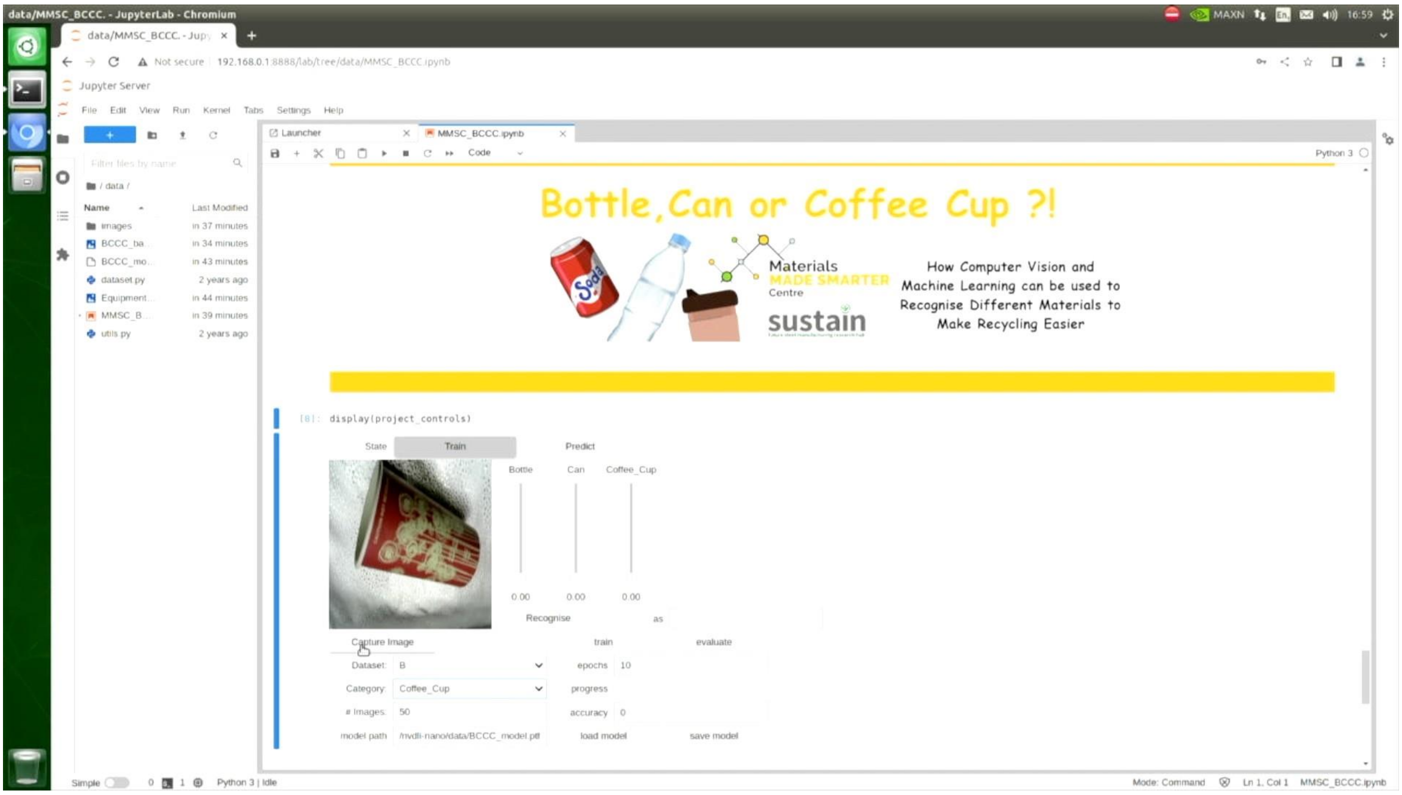
Category: Can

Images: 53

model path: /nvdli-nano/data/BCCC_model.pth

epochs: 10

accuracy: 0



data/MMSC_BCCC. - JupyterLab - Chromium
16:59
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Python 3
Materials MADE SMARTER Centre
sustain
Capture Image
Recognise
train
evaluate
load model
save model
Mode: Command
Ln 1, Col 1
MMSC_BCCC.ipynb

Bottle,Can or Coffee Cup ?!

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[8]: display(project_controls)
```

State: Train

Predict: Bottle 0.00, Can 0.00, Coffee_Cup 0.00

Dataset: B

Category: Coffee_Cup

Images: 50

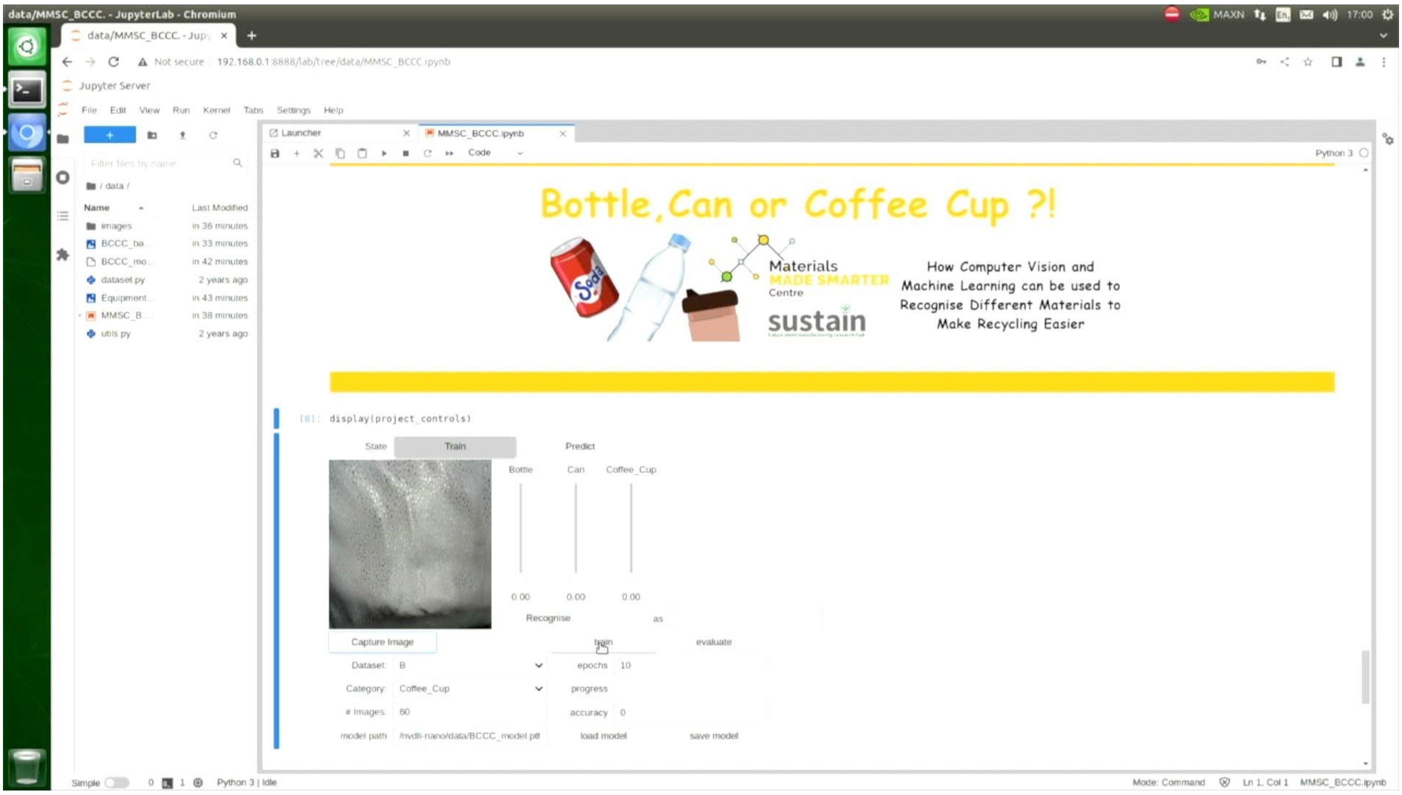
model path: /nvdli-nano/data/BCCC_model.pth

epochs: 10

accuracy: 0

We do the same for the new version of the can and the coffee cup. Make sure that your hand is not present in the captured image and that each object has a good selection of different orientations. Ten new images of each category will be sufficient so the dataset **BCCC_B** contains 60 images of each category.

Thumbnails of the 60 images of the three objects, stored in **BCCC_B** are attached to the end of this guide, 50 of the original objects and 10 of the new versions.


data/MMSC_BCCC. - JupyterLab - Chromium
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Bottle,Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State
Train
Predict
Bottle
Can
Coffee_Cup
Recognise
as
Capture Image
train
evaluate
load model
save model

```
[8]: display(project_controls)
```

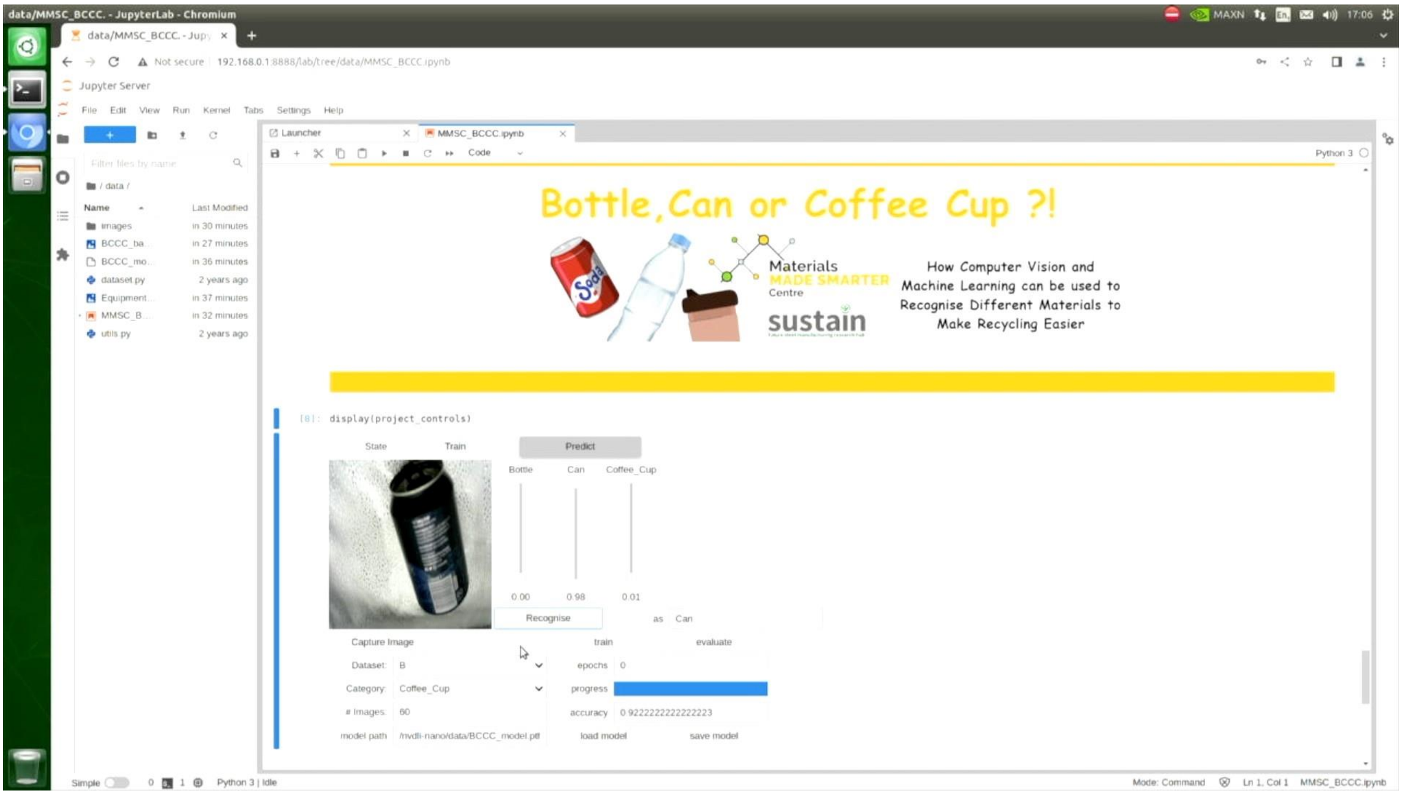
Bottle 0.00, Can 0.00, Coffee_Cup 0.00

Dataset: B
Category: Coffee_Cup
Images: 60
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 10
progress
accuracy: 0

Again with 10 epochs, we are going to train the system on dataset B, 60 images, and see if just those 10 extra images helps it to recognise the coffee cup that it had trouble recognising before.

Even though it was able to recognise the bottle and the can without images of the new objects, it is important to have a balanced dataset, with an equal number of examples of each category.

It will take a bit longer than 4.6 minutes to train this time because there are 30 extra images, which with 10 epochs represents 300 extra training iterations.



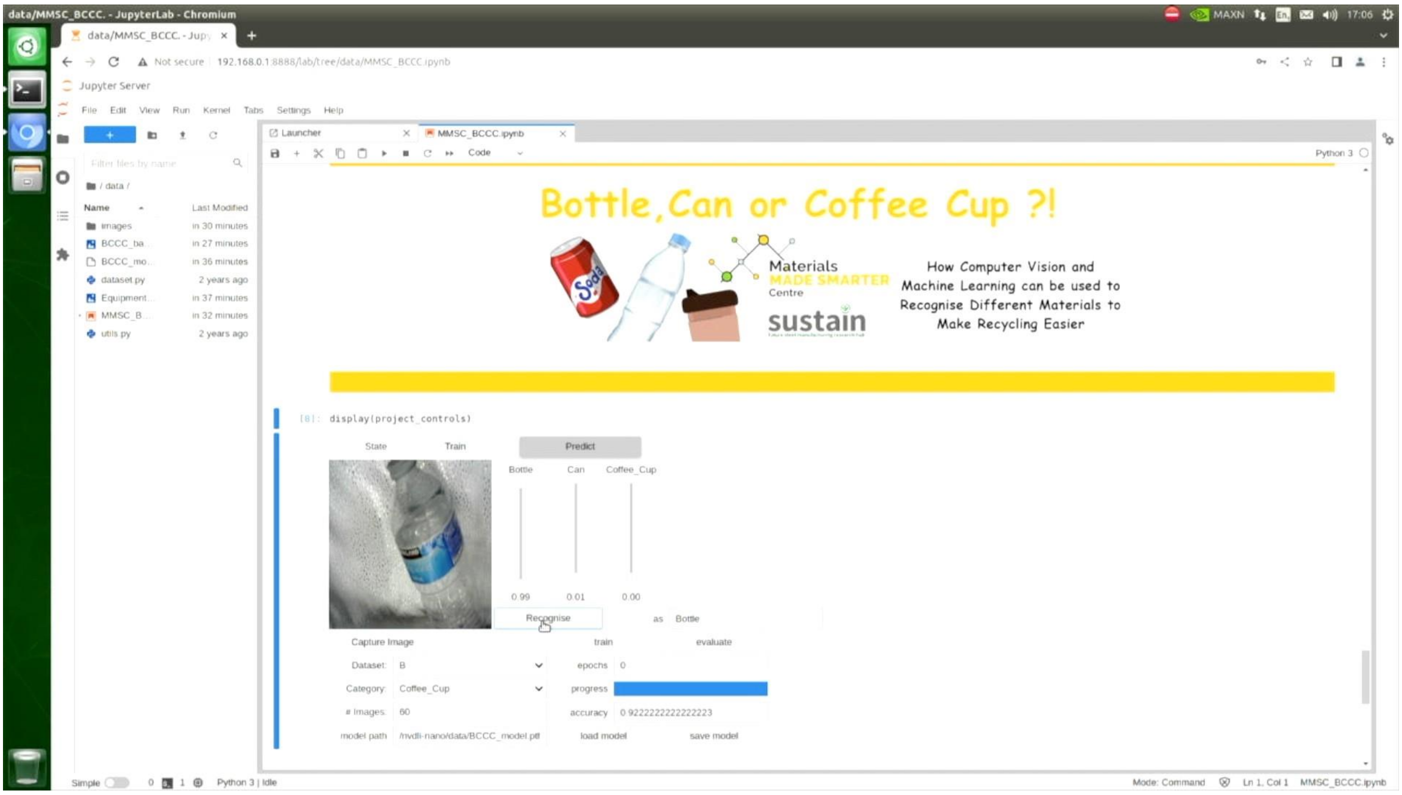
Bottle, Can or Coffee Cup ?!

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[8]: display(project_controls)
```

```
Bottle 0.00   Can 0.98   Coffee_Cup 0.01
as Can
Dataset: B                  epochs 0
Category: Coffee_Cup        progress
# Images: 60                accuracy 0.9222222222222223
model path /nvdli-nano/data/BCCC_model.pth
```

After training, the first time the **Recognize** button is pressed, the process takes a little time as the model is loaded into memory, but after that the recognition process happens in real-time. The can is recognised with 98% confidence.



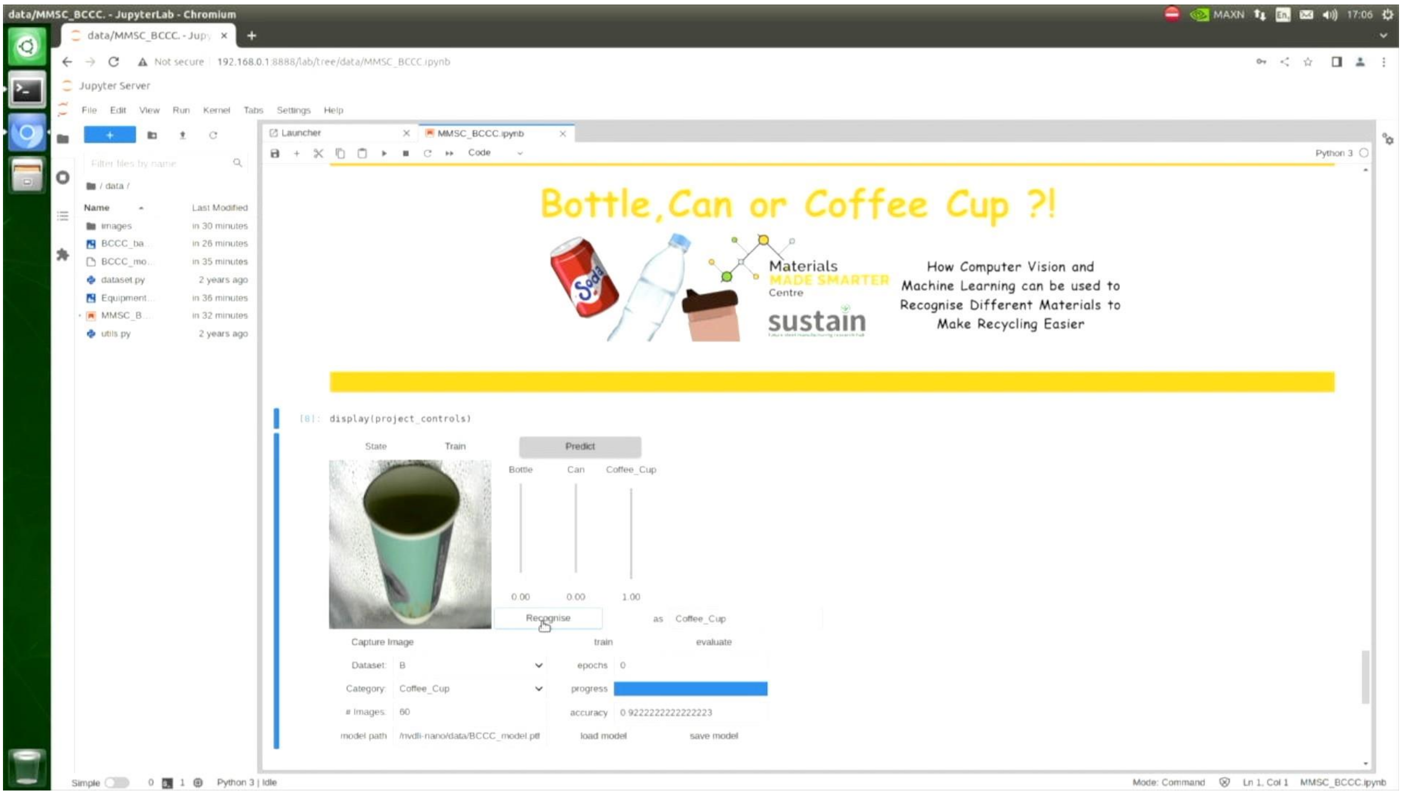
Bottle, Can or Coffee Cup ?!

How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[8]: display(project_controls)
```

```
Bottle 0.99   Can 0.01   Coffee_Cup 0.00
as Bottle
Dataset: B                  epochs 0
Category: Coffee_Cup        progress
# Images: 60                accuracy 0.9222222222222223
model path /nvdli-nano/data/BCCC_model.pth
```

The original bottle with 99% confidence.


data/MMSC_BCCC. - JupyterLab - Chromium
Not secure | 192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
Launcher
MMSC_BCCC.ipynb
Python 3
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State Train Predict
Capture Image
Recognise
train evaluate
load model save model
Mode: Command Ln 1, Col 1 MMSC_BCCC.ipynb

```
[8]: display(project_controls)
```

Bottle 0.00 · Can 0.00 · Coffee_Cup 1.00

Recognise as Coffee_Cup

Dataset: B

Category: Coffee_Cup

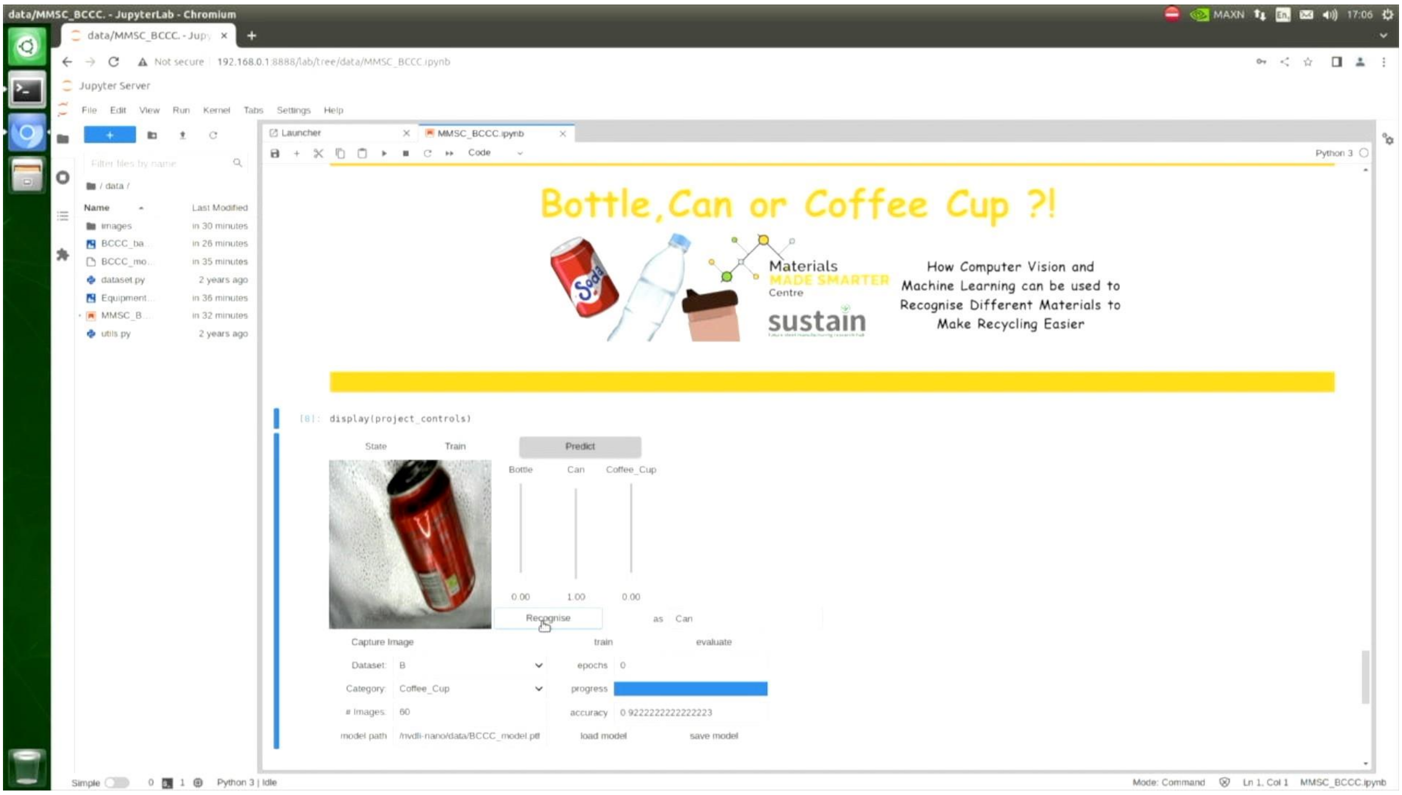
images: 60

model path: /nvdli-nano/data/BCCC_model.pth

epochs: 0

accuracy: 0.9222222222222223

The original coffee cup with 100% confidence.


data/MMSC_BCCC. - JupyterLab - Chromium
Not secure | 192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Jupyter Server
File Edit View Run Kernel Tabs Settings Help
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MMSC_BCCC.ipynb
Python 3
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier
State Train Predict
Capture Image
Recognise
train evaluate
load model save model
Mode: Command Ln 1, Col 1 MMSC_BCCC.ipynb

```
[8]: display(project_controls)
```

Bottle 0.00 · Can 1.00 · Coffee_Cup 0.00

Recognise as Can

Dataset: B

Category: Coffee_Cup

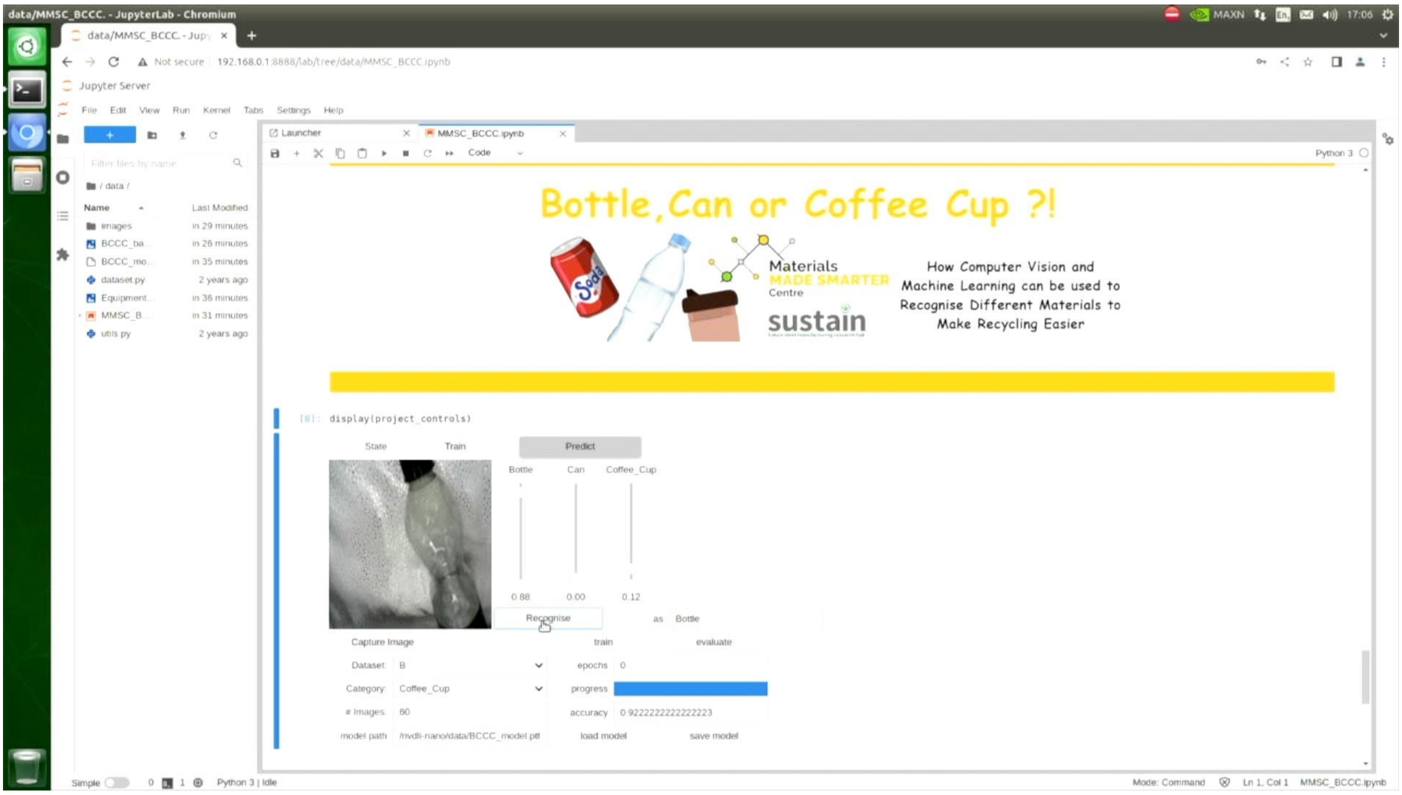
images: 60

model path: /nvdli-nano/data/BCCC_model.pth

epochs: 0

accuracy: 0.9222222222222223

The new can with 100% confidence.


data/MMSC_BCCC. - JupyterLab - Chromium
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
State
Train
Predict
Recognise
Capture Image
train
evaluate
load model
save model

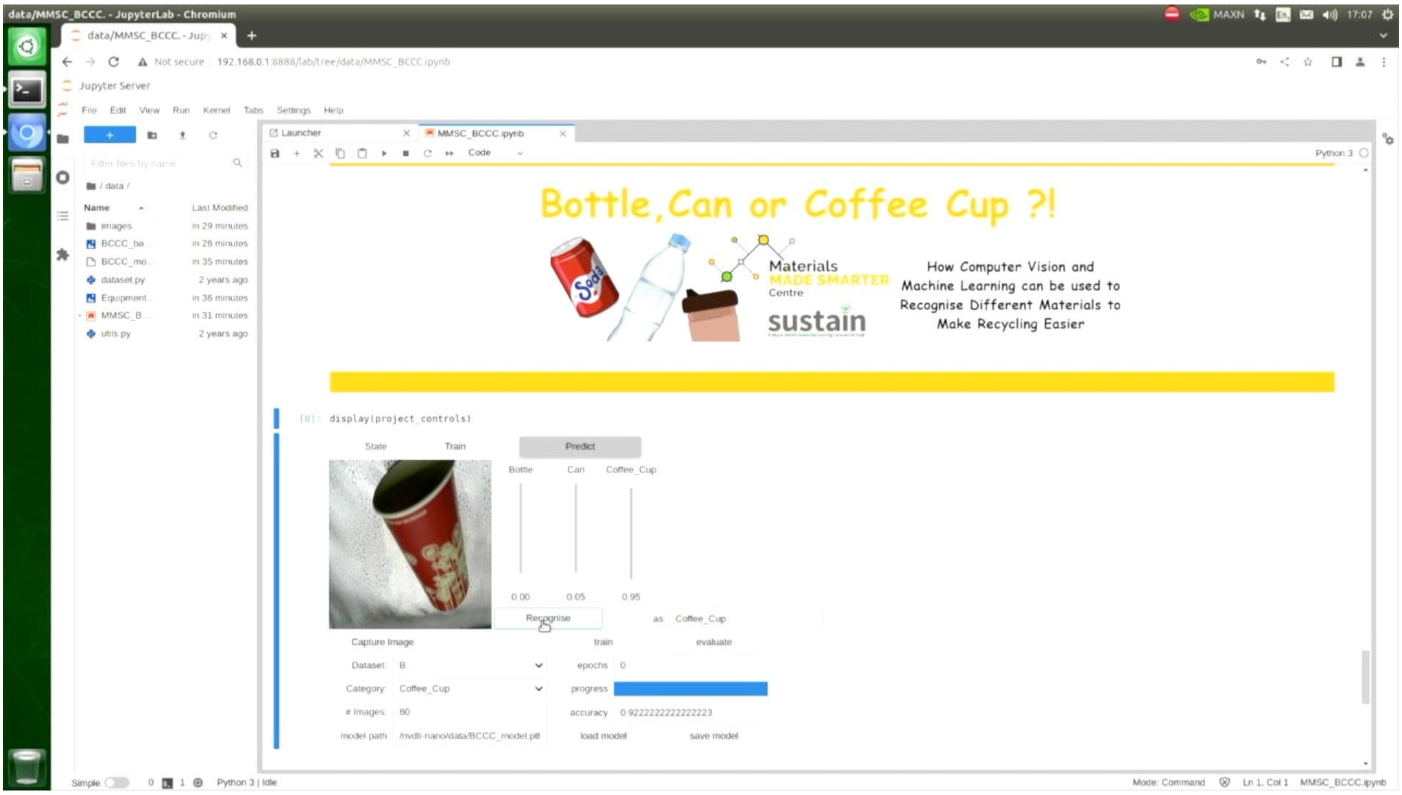
How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[8]: display(project_controls)
```

Bottle 0.88 | Can 0.00 | Coffee_Cup 0.12 — Recognise as Bottle

Dataset: B
Category: Coffee_Cup
Images: 60
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 0
accuracy: 0.9222222222222223

The new bottle with 88% confidence.


data/MMSC_BCCC. - JupyterLab - Chromium
192.168.0.1:8888/lab/tree/data/MMSC_BCCC.ipynb
Bottle, Can or Coffee Cup ?!
Materials MADE SMARTER Centre
sustain
State
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How Computer Vision and Machine Learning can be used to Recognise Different Materials to Make Recycling Easier

```
[8]: display(project_controls)
```

Bottle 0.00 | Can 0.05 | Coffee_Cup 0.95 — Recognise as Coffee_Cup

Dataset: B
Category: Coffee_Cup
Images: 60
model path: /nvdli-nano/data/BCCC_model.pth
epochs: 0
accuracy: 0.9222222222222223

And then, finally, the new coffee cup with 95% confidence on the new coffee cup.

You can see in this straightforward demonstration how it is possible to re-train machine learning using just a few extra images to really improve its understanding of a new object without having to train from scratch every single time on exactly what is a bottle, a can or a coffee cup. Have fun playing around with the demonstration and I'll see you next time.

./data/images/BCCC_A/Bottle/

0e51f56e-d430-11ef-9eca-48b02d9b1de8

1c4c3b2a-d430-11ef-9eca-48b02d9b1de8

02fdf0f4-d440-11ef-ad7d-48b02d9b1de8

2c5d7042-d430-11ef-9eca-48b02d9b1de8

2f018d06-d430-11ef-9eca-48b02d9b1de8

3a23129a-d430-11ef-9eca-48b02d9b1de8

04c9bbbc-d430-11ef-9eca-48b02d9b1de8

09d10e9e-d430-11ef-9eca-48b02d9b1de8

13fe9ddc-d430-11ef-9eca-48b02d9b1de8

26a023d4-d430-11ef-9eca-48b02d9b1de8

32c15034-d430-11ef-9eca-48b02d9b1de8

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204fe1ae-d430-11ef-9eca-48b02d9b1de8

230ff56e-d430-11ef-9eca-48b02d9b1de8

1984a512-d430-11ef-9eca-48b02d9b1de8

06158388-d440-11ef-ad7d-48b02d9b1de8

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a743f25a-d42f-11ef-9eca-48b02d9b1de8

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aea09fee-d42f-11ef-9eca-48b02d9b1de8

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bc6d9f0a-d42f-11ef-9eca-48b02d9b1de8

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c64aa216-d42f-11ef-9eca-48b02d9b1de8

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ffadf0a2-d43f-11ef-ad7d-48b02d9b1de8

./data/images/BCCC_A/Can/

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fe95d0de-d43c-11ef-be21-48b02d9b1de8

./data/images/BCCC_A/Coffee_Cup/

0d828bc4-d432-11ef-9eca-48b02d9b1de8

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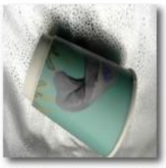
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fc976a42-d430-11ef-9eca-48b02d9b1de8

./data/images/BCCC_B/Bottle/

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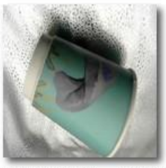
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