

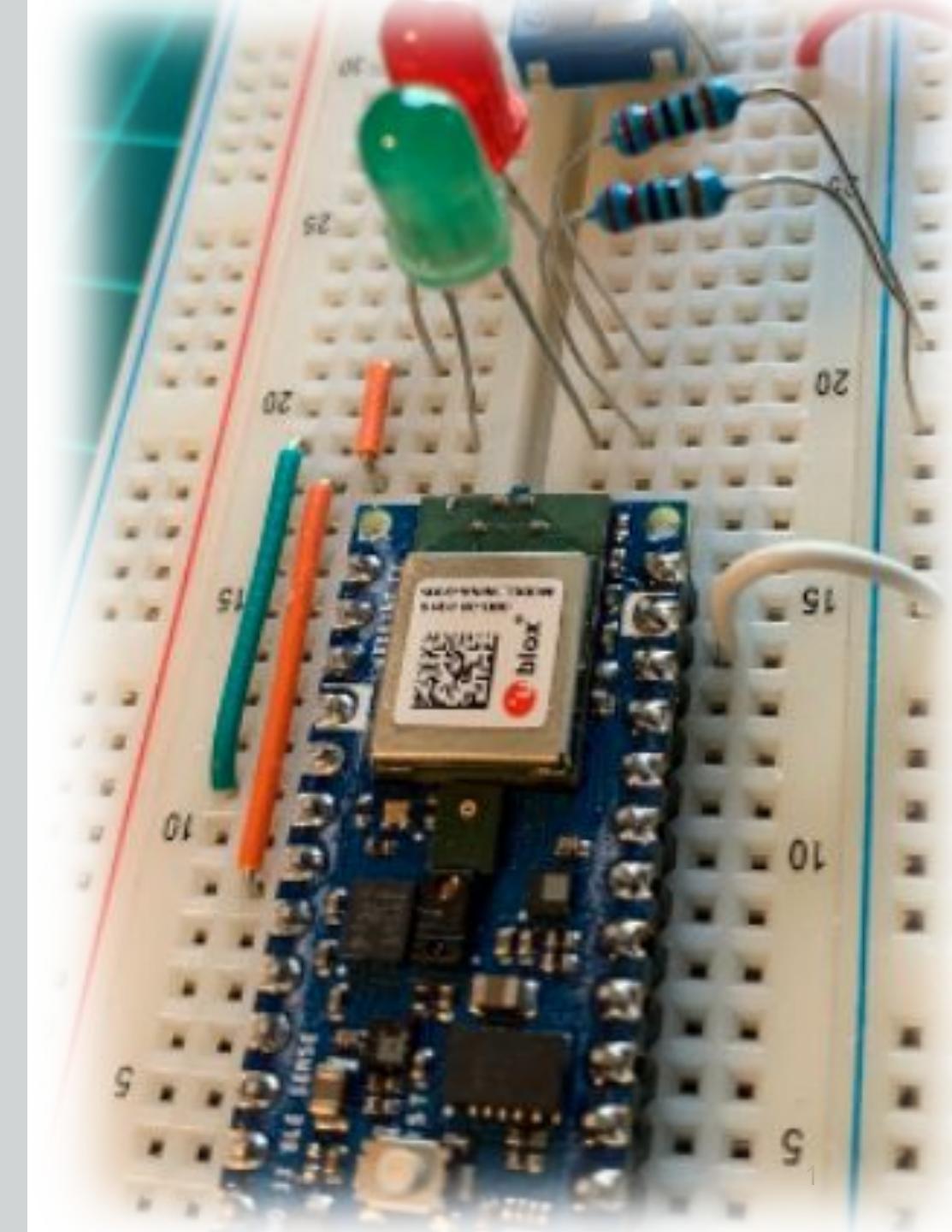
IESTI01 – TinyML

Embedded Machine Learning

12. Preventing Overfitting



Prof. Marcelo Rovai
UNIFEI



Preventing Overfitting

Preventing Overfitting

+Data

+Data

+Data

+Data

Preventing Overfitting

+Data

+Data

+Data

+Data

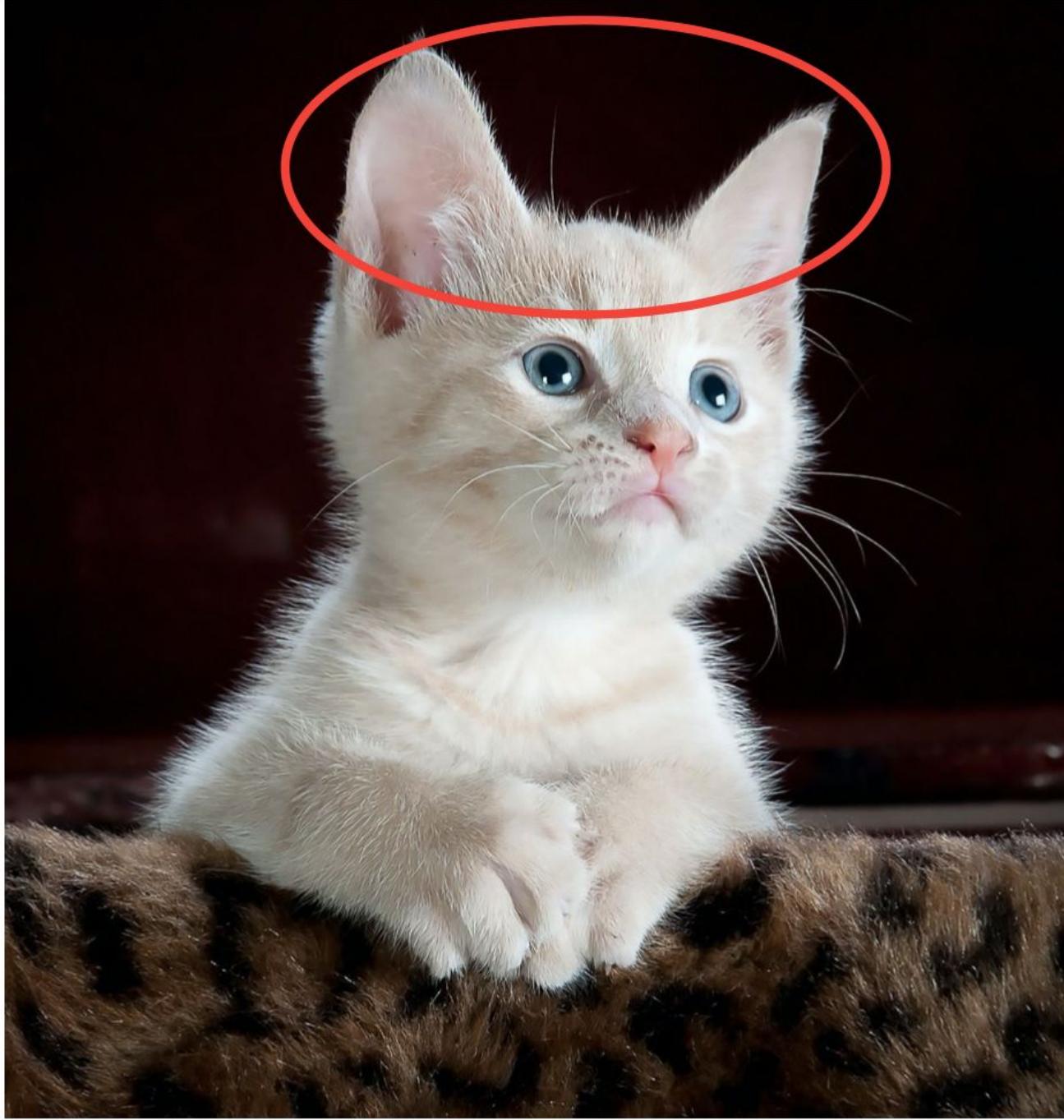
But what to do if we do
not have more data?

- Data Augmentation (artificial)
- Transfer Learning
- Early Stopping
- Dropout Regularization

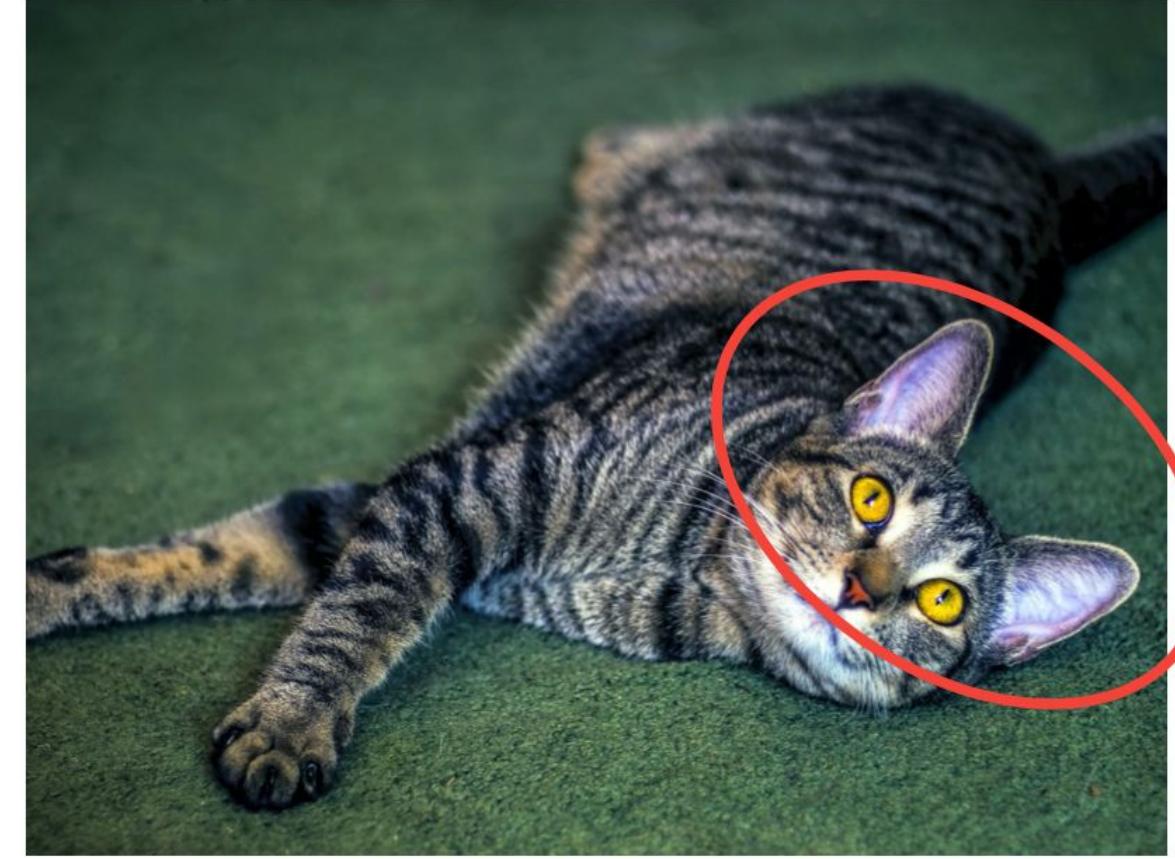
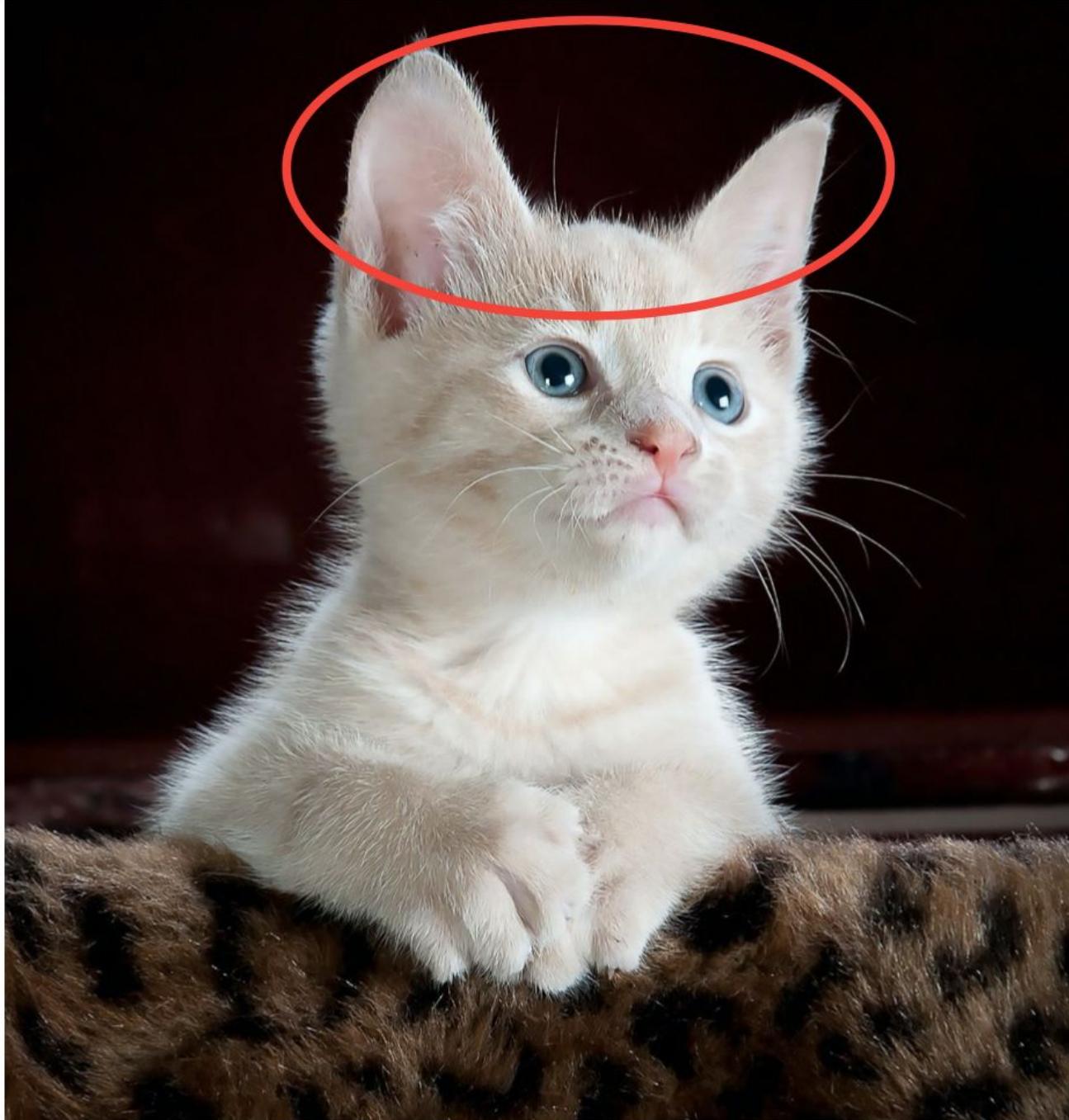
Preventing Overfitting

More Data, Data Augmentation (artificial)

Overfitting generally occurs when there are a small number of training examples. Data augmentation takes the approach of generating additional training data from your existing examples by augmenting them using random transformations that yield believable-looking images. This helps expose the model to more aspects of the data and generalize better.



← Training

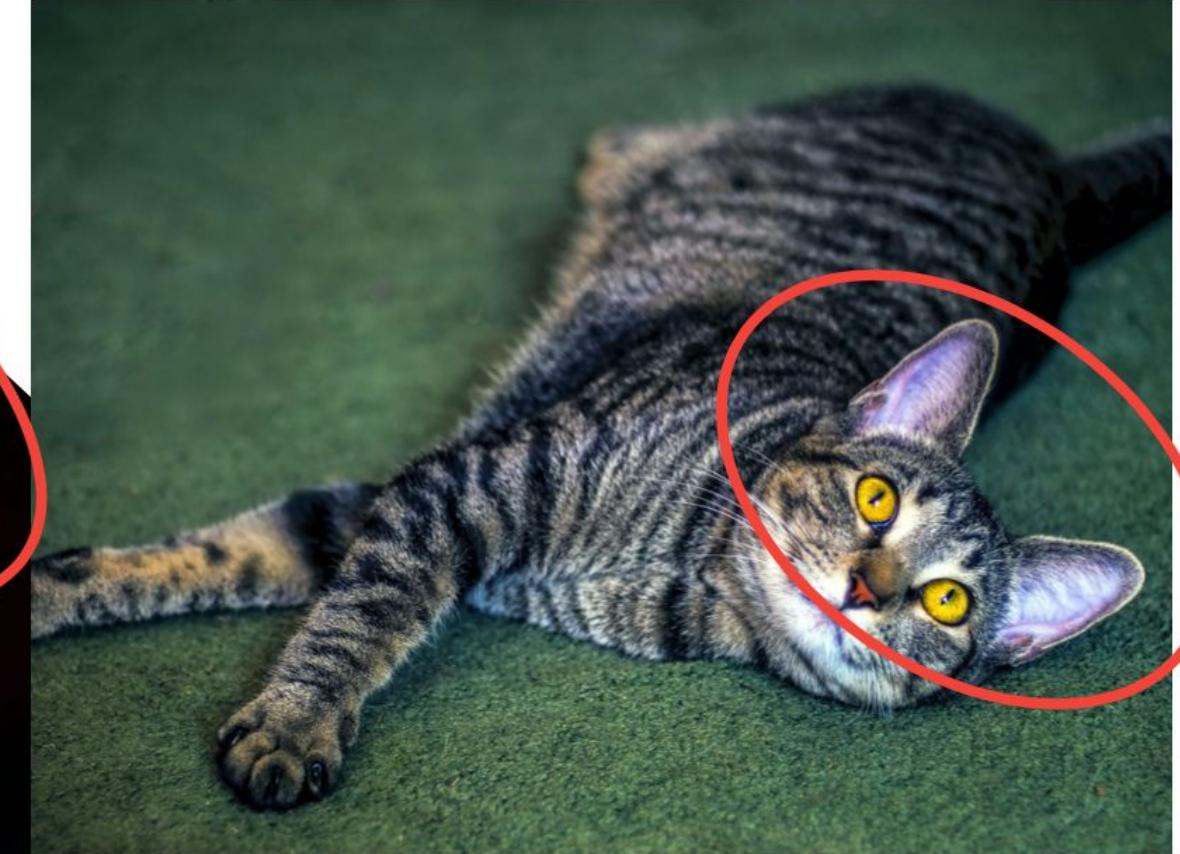
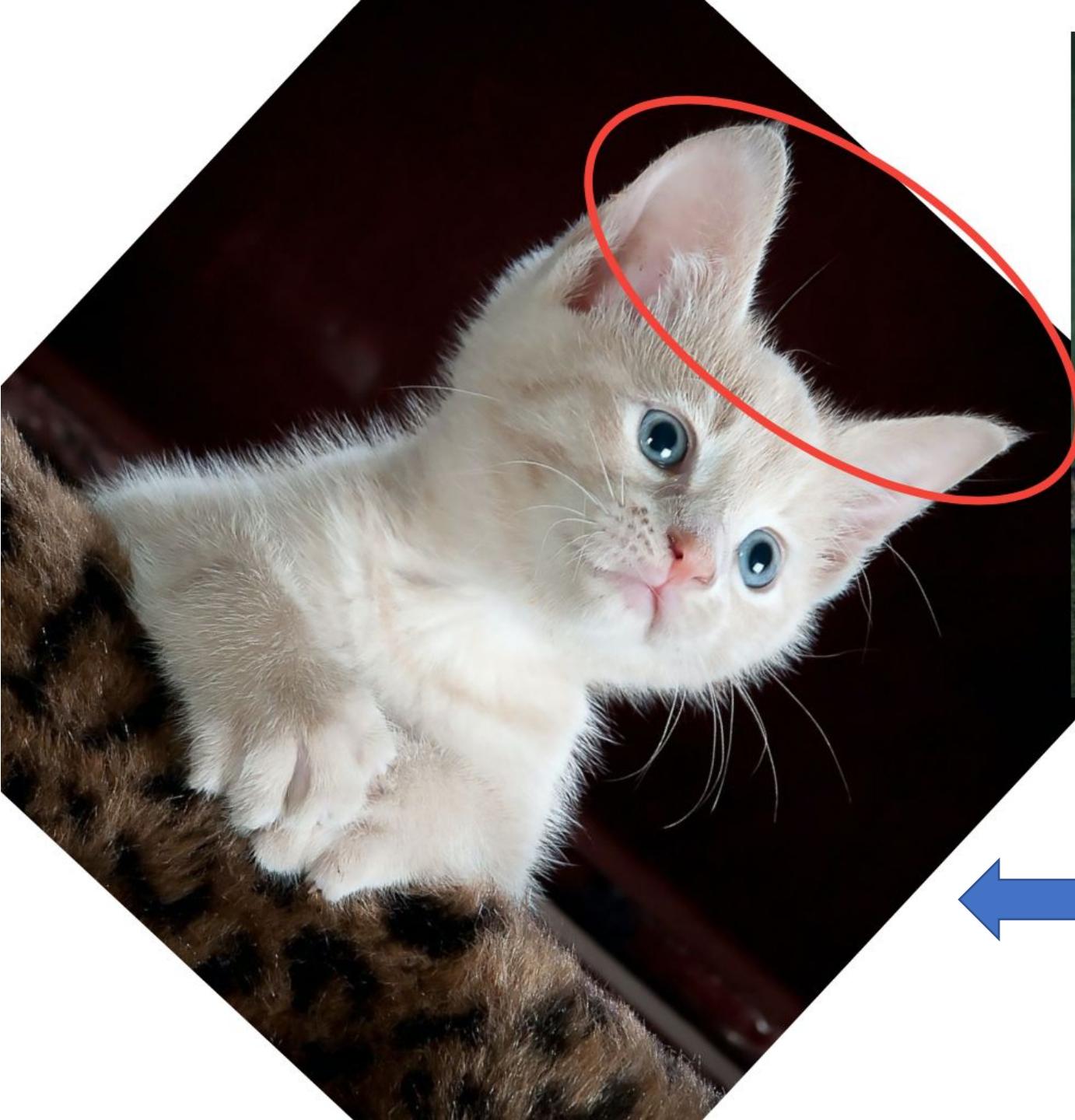


← Training



Inference





Training with
Data Augmentation



Using Keras preprocessing layers

```
1 data_augmentation = tf.keras.Sequential([
2     layers.RandomFlip("horizontal_and_vertical"),
3     layers.RandomRotation(0.2),
4 ])
```



```
1 plt.figure(figsize=(10, 10))
2 for i in range(9):
3     augmented_image = data_augmentation(image)
4     ax = plt.subplot(3, 3, i + 1)
5     plt.imshow(augmented_image[0])
6     plt.axis("off")
```



There are a variety of preprocessing layers you can use for data augmentation including:

- tf.keras.layers.RandomContrast,
- tf.keras.layers.RandomCrop,
- tf.keras.layers.RandomZoom,
- and others.



Using tf.image

```
1 flipped = tf.image.flip_left_right(image)
2 visualize(image, flipped)
```

Original image



Augmented image



```
1 rotated = tf.image.rot90(image)
2 visualize(image, rotated)
```

Original image

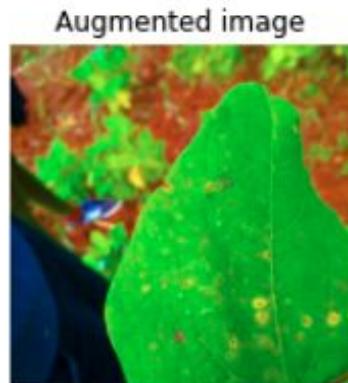


Augmented image

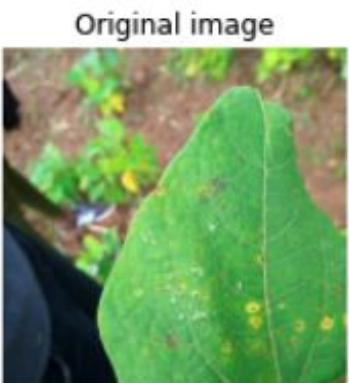


Using tf.image

```
1 saturated = tf.image.adjust_saturation(image, 3)
2 visualize(image, saturated)
```



```
1 bright = tf.image.adjust_brightness(image, 0.4)
2 visualize(image, bright)
```



```
1 for i in range(3):
2   seed = (i, 0) # tuple of size (2,)
3   stateless_random_crop = tf.image.stateless_random_crop(
4     image, size=[210, 300, 3], seed=seed)
5   visualize(image, stateless_random_crop)
```

Original image



Original image



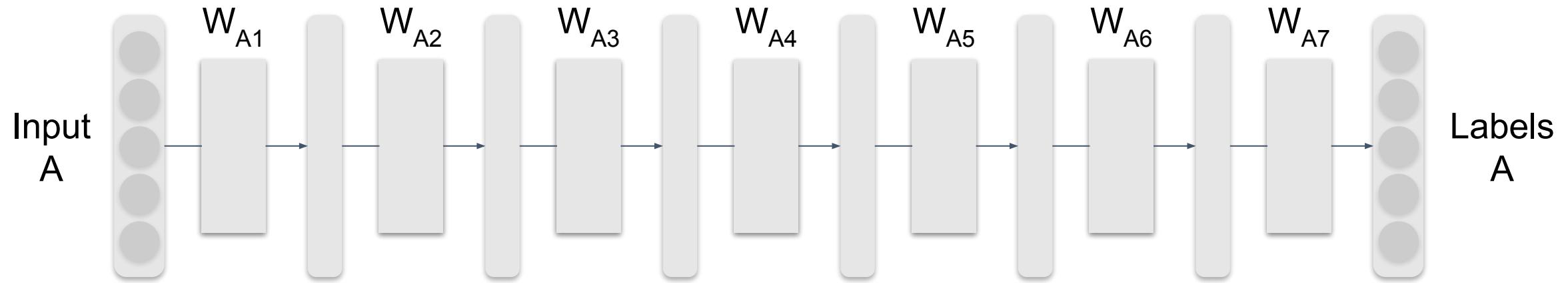
Original image



Preventing Overfitting

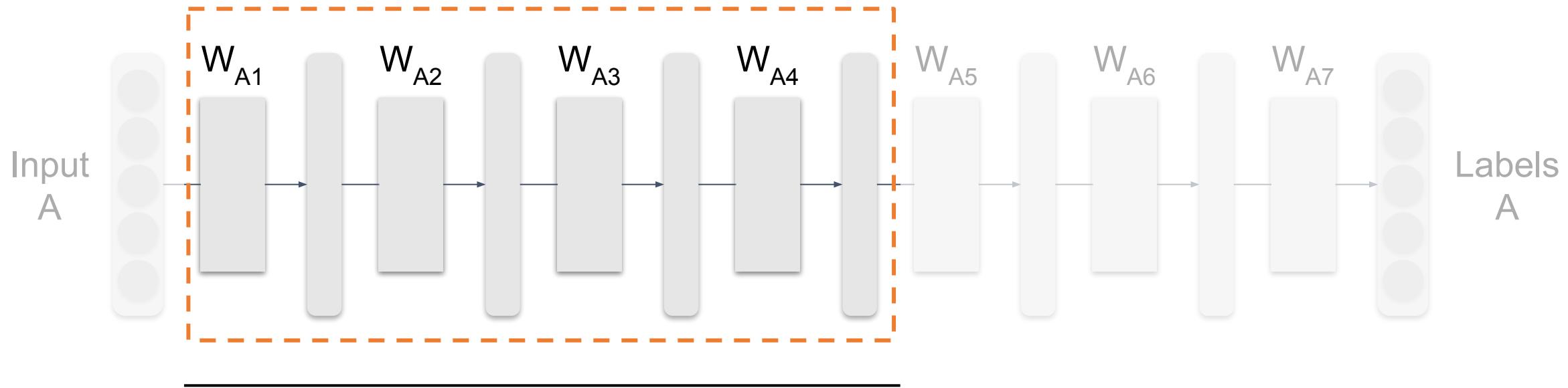
Transfer Learning

End Result of Training



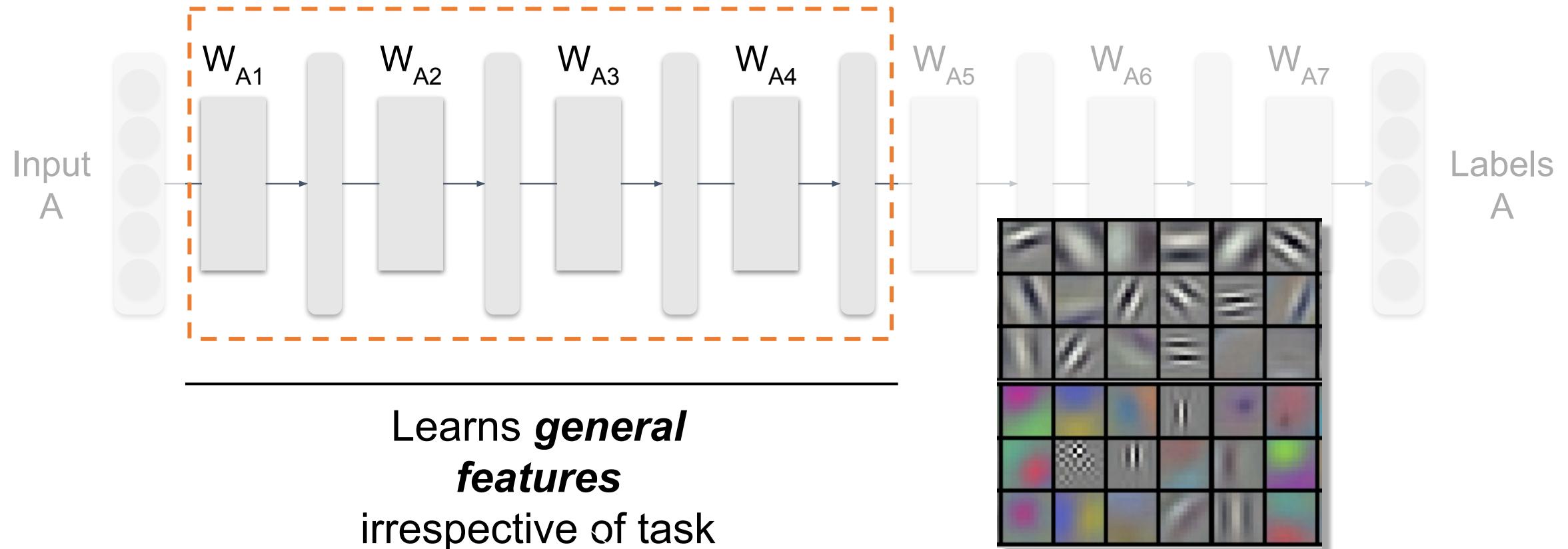
The end result of the training is to learn the weights of the neural network model.

End Result of Training

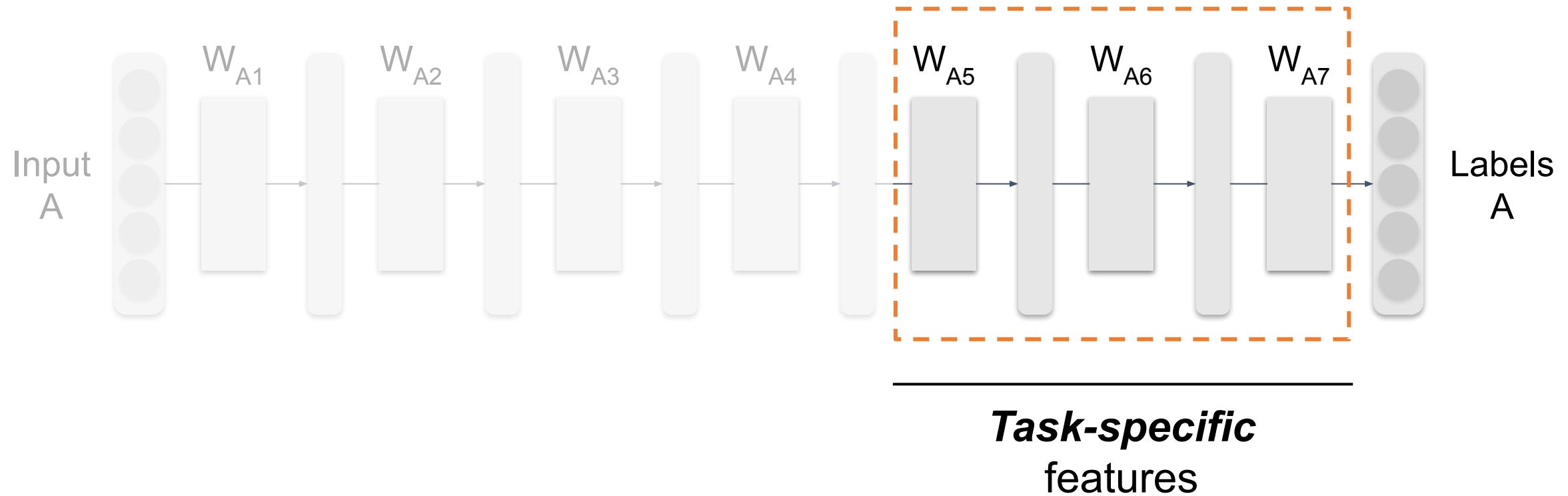


Learns ***general features***
irrespective of task

End Result of Training



End Result of Training

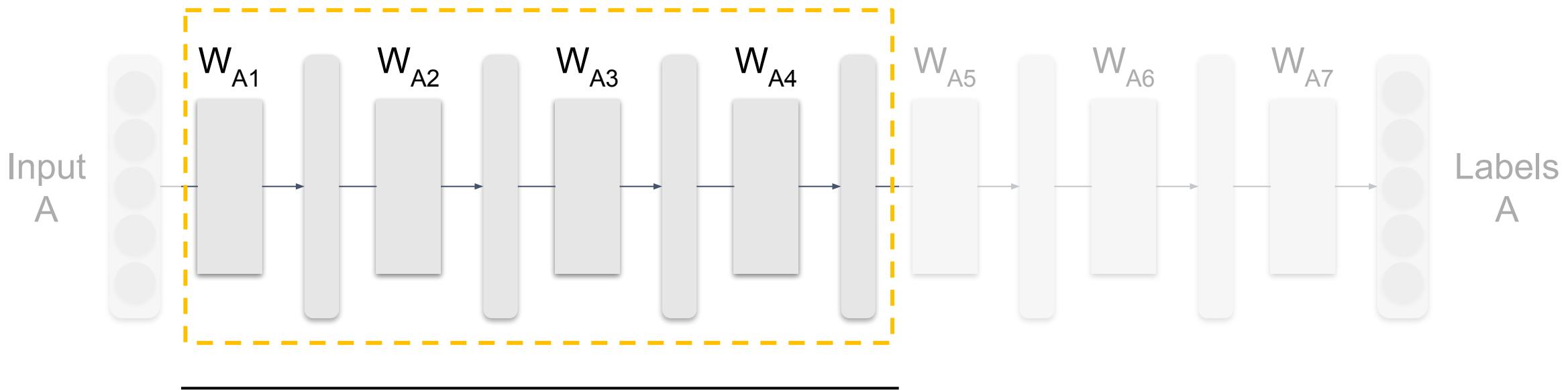




Source: Google

Transfer Learning

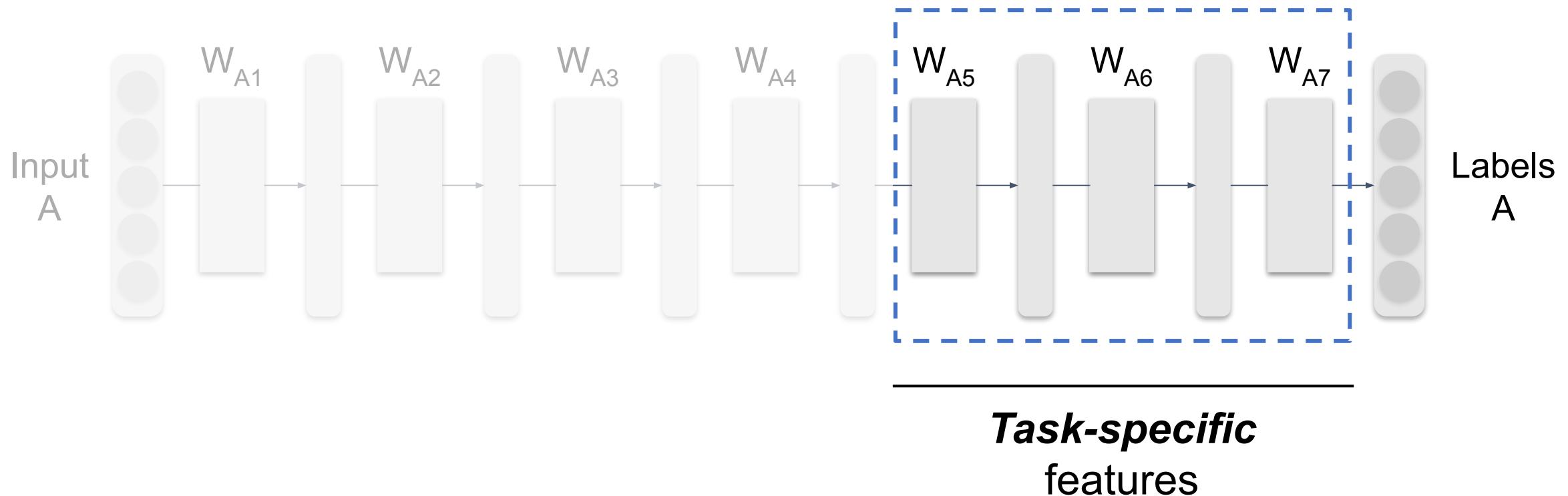
Reuse (freeze general feature extraction)



Learns ***general features***
irrespective of task

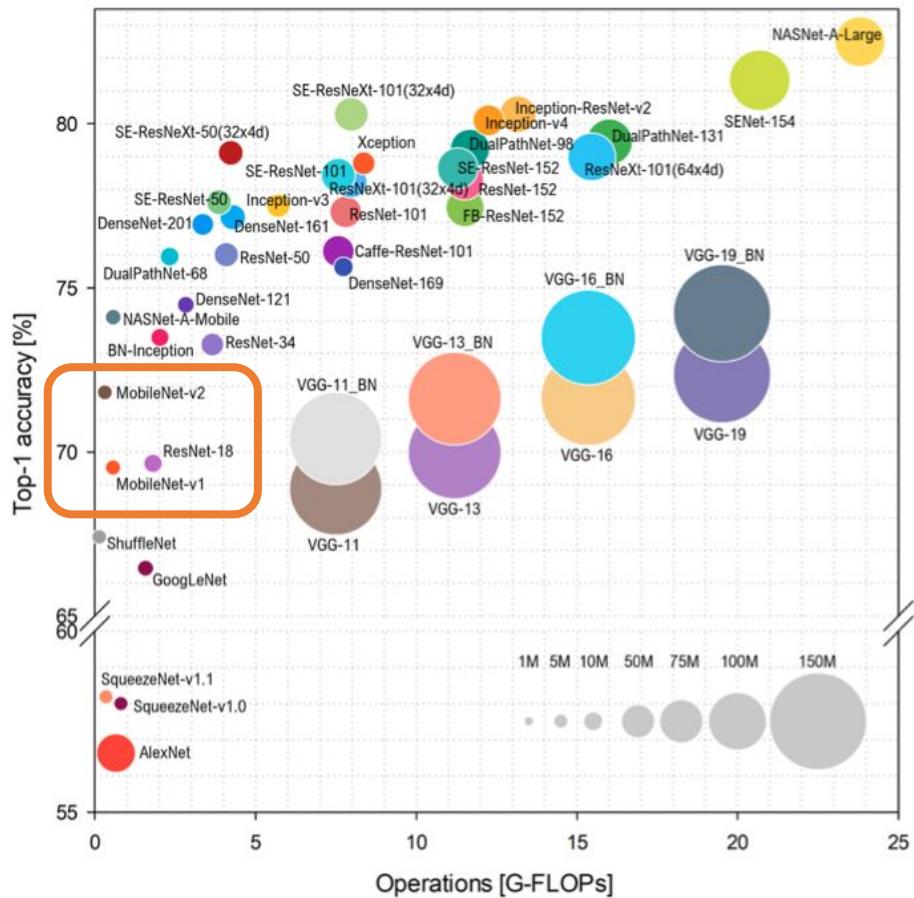
Transfer Learning

Train **only** last
few layers





EON Tuner



<https://arxiv.org/pdf/1810.00736.pdf>

79% image-conv2d-64c Select

PERFORMANCE

ACCURACY

INPUT

↔ 32 | ↴ 32

IMAGE

RGB

KERAS

Type	Filters	Kernel	Rate
conv2d	32	3	-
conv2d	64	3	-
conv2d	128	3	-
dropout	-	-	0.25
dense	64	-	-
dropout	-	-	0.25

TRANSFER LEARNING

MobileNetV1 0.1
→ 16 | ↓ 0.1 | ↴ 16

10/9/2021, 2:28:32 PM

63% grayscale-v1_a1_d100-5ff Select

PERFORMANCE

ACCURACY

INPUT

↔ 96 | ↴ 96

IMAGE

Grayscale

TRANSFER LEARNING

MobileNetV2 0.05
→ 16 | ↓ 0.25 | ↴ 16

10/9/2021, 5:17:05 PM

65% rgb-v2_a05-2ad Select

PERFORMANCE

ACCURACY

INPUT

↔ 96 | ↴ 96

IMAGE

RGB

TRANSFER LEARNING

MobileNetV2 0.05
→ 16 | ↓ 0.25 | ↴ 16

10/9/2021, 5:17:05 PM

iBean

Detecting Diseases in the Bean plants



AIR Lab Makerere University

UGANDA



iBean Dataset



Angular Leaf Spot

Bean Rust

Healthy

This dataset is of leaf images taken in the field in different districts in Uganda by the Makerere AI lab in collaboration with the National Crops Resources Research Institute (NaCRRI), the national body in charge of research in agriculture in Uganda.

Goal:

To build a neural network that can tell the difference between the healthy and diseased leaves.

Dataset:

Training, Test and Validation data based on 224x224 pixel color images taken of bean plants in Uganda.

Class	Examples
Healthy class	428
Angular Leaf Spot	432
Bean Rust	436
Total:	1,296

Dataset: <https://github.com/AI-Lab-Makerere/ibean/>

Data acquisition - Bean Diseases

studio.edgeimpulse.com/studio/51151/acquisition/training?page=1

EDGE IMPULSE

DATA ACQUISITION (BEAN DISEASE CLASSIFIER)

Training data Test data

Did you know? You can capture data from any device or development board, or upload your existing datasets - Show options

DATA COLLECTED 1,167 items

TRAIN / TEST SPLIT 90% / 10%

Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
healthy_val.43.jpg.2hi4mtro	healthy	Today, 13:20:13	-
healthy_val.42.jpg.2hi4mtmt	healthy	Today, 13:20:13	-
healthy_val.41.jpg.2hi4mtka	healthy	Today, 13:20:13	-
healthy_val.40.jpg.2hi4mtk2	healthy	Today, 13:20:13	-
healthy_val.39.jpg.2hi4mtja	healthy	Today, 13:20:13	-
healthy_val.38.jpg.2hi4mte0	healthy	Today, 13:20:12	-
healthy_val.37.jpg.2hi4mtcb	healthy	Today, 13:20:12	-
healthy_val.36.jpg.2hi4mtbq	healthy	Today, 13:20:12	-
healthy_val.23.jpg.2hi4mt4a	healthy	Today, 13:20:12	-
healthy_val.29.jpg.2hi4mt40	healthy	Today, 13:20:12	-
healthy_val.34.jpg.2hi4mt47	healthy	Today, 13:20:12	-
healthy_val.26.jpg.2hi4mt3u	healthy	Today, 13:20:12	-

Record new data

Connect using WebUSB

No devices connected to the remote management API.

RAW DATA

healthy_val.43.jpg.2hi4mtro



Create impulse - Bean Disease

studio.edgeimpulse.com/studio/51151/create-impulse

EDGE IMPULSE

CREATE IMPULSE (BEAN DISEASE CLASSIFIER)

An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

Dashboard

Devices

Data acquisition

Impulse design

Create impulse

Image

NN Classifier

EON Tuner

Retrain model

Live classification

Model testing

Versioning

Deployment

GETTING STARTED

Documentation

Forums

Image data

Axes
image

Image width 224 Image height 224

Resize mode Fit shortest axis

For optimal accuracy with transfer learning blocks, use a 96x96 or 160x160 image size.

Image

Name Image

Input axes image

Classification (Keras)

Name NN Classifier

Input features Image

Output features 3 (angular_leaf_spot, bean_rust, healthy)

Output features

3 (angular_leaf_spot, bean_rust, healthy)

Add a processing block

Add a learning block

Save Impulse

MJRoBot (Marcelo Rovai)

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Image - Bean Disease Classifier

studio.edgeimpulse.com/studio/51151/dsp/image/3

EDGE IMPULSE

IMAGE (BEAN DISEASE CLASSIFIER)

#1 Click to set a description for this version

Parameters Generate features

Raw data

healthy_val.43.jpg.2hi4mtro (healthy)

Raw features

0x397903, 0x316b01, 0x3a7204, 0x649c25, 0x70ab2f, 0x6faa31, 0x63a226, 0x66a821, 0x62a014, 0x5897...

Parameters

Image

Color depth

RGB

Save parameters

DSP result

Image

Processed features

0.2235, 0.4745, 0.0118, 0.1922, 0.4196, 0.0039, 0.2275, 0.4471, 0.0157, 0.3922, 0.6118, 0.1451, ...

On-device performance

PROCESSING TIME 4 ms.

PEAK RAM USAGE 4 KB

MJRoBot (Marcelo Rovai)

Image - Bean Disease Classification

studio.edgeimpulse.com/studio/51151/dsp/image/3/generate-features#!

#1 Click to set a description for this version

EDGE IMPULSE

Parameters Generate features

Training set

Data in training set 1,167 items

Classes 3 (angular_leaf_spot, bean_rust, healthy)

Generate features

Feature explorer (1,167 samples)

X Axis image Feature 0 Y Axis image Feature 1 Z Axis image Feature 2

Angular leaf spot (blue), Bean rust (orange), Healthy (green)

bean_rust_val.20.jpg.2hi4ikh7 Label: bean_rust View sample View features

On-device performance

PROCESSING TIME 4 ms. PEAK RAM USAGE 4 KB

Dashboard Devices Data acquisition Impulse design Create impulse Image NN Classifier EON Tuner Retrain model Live classification Model testing Versioning Deployment

GETTING STARTED Documentation Forums

studio.edgeimpulse.com/studio/51151/learning/keras/5

NN CLASSIFIER (BEAN DISEASE CLASSIFIER)

#1 ▾ Click to set a description for this version

Neural Network settings

Training settings

Number of training cycles ⑦

Learning rate ⑦

Neural network architecture

- Input layer (150,528 features)**
- 2D conv / pool layer (16 filters, 3 kernel size, 1 layer)
- 2D conv / pool layer (32 filters, 3 kernel size, 1 layer)
- 2D conv / pool layer (64 filters, 3 kernel size, 1 layer)
- 2D conv / pool layer (128 filters, 3 kernel size, 1 layer)
- Flatten layer
- Dense layer (512 neurons)
- Add an extra layer
- Output layer (3 features)**

Start training

Training output

Model

Model version: ⑦ Quantized (int8) ▾

Last training performance (validation set)

 ACCURACY	76.9%	 LOSS	0.57
---	--------------	---	-------------

Confusion matrix (validation set)

	ANGULAR_LEAF_SPOT	BEAN_RUST	HEALTHY
ANGULAR_LEAF_SPOT	84.8%	10.1%	5.1%
BEAN_RUST	34.2%	48.7%	17.1%
HEALTHY	1.3%	2.5%	96.2%
F1 SCORE	0.77	0.60	0.88

Feature explorer (full training set) ⑦

image Feature 0 image Feature 1 image Feature 2

Legend:

- angular_leaf_spot - correct
- bean_rust - correct
- healthy - correct
- angular_leaf_spot - incorrect
- bean_rust - incorrect
- healthy - incorrect

angular_leaf_spot_train.300.jpg.2hi...
Label: angular_leaf_spot
Predicted: angular_leaf_spot
[View sample](#)
[View features](#)

Model testing - Bean Disease +

studio.edgeimpulse.com/studio/51151/validation

EDGE IMPULSE

Test data

Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse.

SAMPLE NAME	EXPECTED OUTCOME	LENGTH	ACCURACY	RESULT	...
healthy_test.39....	healthy	-	100%	1 healthy	...
healthy_test.38....	healthy	-	100%	1 healthy	...
healthy_test.37....	healthy	-	100%	1 healthy	...
healthy_test.36....	healthy	-	0%	1 uncertain	...
healthy_test.35....	healthy	-	100%	1 healthy	...
healthy_test.34....	healthy	-	100%	1 healthy	...
healthy_test.33....	healthy	-	100%	1 healthy	...
healthy_test.32....	healthy	-	100%	1 healthy	...
healthy_test.29....	healthy	-	100%	1 healthy	...
healthy_test.31....	healthy	-	100%	1 healthy	...
healthy_test.30....	healthy	-	100%	1 healthy	...
healthy_test.26....	healthy	-	100%	1 healthy	...
healthy_test.27....	healthy	-	0%	1 uncertain	...

Model testing output

Classifying data for NN classifier...
 Copying features from processing blocks...
 Copying features from DSP block...
 Copying features from DSP block OK
 Copying features from processing blocks OK

Classifying data for float32 model...
 Scheduling job in cluster...
 Job started
 Classifying data for NN Classifier OK

Job completed

Model testing results

ACCURACY **67.19%**

	ANGULAR_LEAF_SPOT	BEAN_RUST	HEALTHY	UNCERTAIN
ANGULAR_LEAF_SPOT	81.4%	2.3%	2.3%	14.0%
BEAN_RUST	34.9%	27.9%	4.7%	32.6%
HEALTHY	0%	0%	92.9%	7.1%
F1 SCORE	0.75	0.43	0.93	

Feature explorer

image Feature 0 image Feature 1 image Feature 2

Legend:

- angular_leaf_spot - correct (green)
- bean_rust - correct (green)
- healthy - correct (green)
- angular_leaf_spot - incorrect (red)
- bean_rust - incorrect (red)
- healthy - incorrect (red)

Live classification - Bean Disease

studio.edgeimpulse.com/studio/51151/classification#load-sample-49581902

EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
 - Create impulse
 - Image
 - NN Classifier
- EON Tuner
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

GETTING STARTED

- Documentation
- Forums

Classify new data

Device: phone_kujx409d

Sensor: Camera

Sample length (ms):

Frequency: Frequency selection not supported

Start sampling

Classify existing test sample

healthy_test.41.jpg.2hi4nrnr (healthy)

Load sample

Classification result

Summary

Name	testing.2hio9ui3
Expected outcome	testing

CATEGORY	COUNT
angular_leaf_spot	0
bean_rust	0
healthy	1
uncertain	0

Detailed result

ANGULAR LEAF SPOT	BEAN RUST	HEALTHY
0	0	0.99

Show only unknowns

Raw DATA

testing.2hio9ui3

Raw features

```
0xf3d7e5, 0xf1dbe1, 0xeaddfa, 0xf0e2de, 0xd4d3d7, 0xa7a491, 0xc6b16b, 0xdec66a, 0xeac862, 0xf1c557, 0xf3bd4a, 0xf4ba37, 0x...
```

Image (1,168 samples)

X Axis: image Feature 0

Y Axis: image Feature 1

Z Axis: image Feature 2

Legend:

- angular_leaf_spot
- bean_rust
- healthy
- classification 0

Live classification - Bean Disease

studio.edgeimpulse.com/studio/51151/classification#load-sample-49581906

EDGE IMPULSE

- [Dashboard](#)
- [Devices](#)
- [Data acquisition](#)
- [Impulse design](#)
- [Create impulse](#)
- [Image](#)
- [NN Classifier](#)
- [EON Tuner](#)
- [Retrain model](#)
- [Live classification](#)
- [Model testing](#)
- [Versioning](#)
- [Deployment](#)

GETTING STARTED

- [Documentation](#)
- [Forums](#)

Classify new data

Device: phone_kujx409d

Sensor: Camera

Sample length (ms):

Frequency: Frequency selection not supported

Start sampling

Classify existing test sample

healthy_test.41.jpg.2hi4nrnr (healthy)

Load sample

Classification result

Summary

Name	testing.2hiodaqp
Expected outcome	testing

CATEGORY	COUNT
angular_leaf_spot	0
bean_rust	0
healthy	1
uncertain	0

Detailed result

Category	Probability
ANGULAR LEAF SPOT	0.07
BEAN RUST	0
HEALTHY	0.93

Show only unknowns

Healthy

RAW DATA
testing.2hiodaqp



Raw features

```
0xe3d3ce, 0xdbd4cc, 0xe0d7ce, 0xe4d7ce, 0xe1d8ce, 0xe8d7cf, 0xe0d5cc, 0xd9dc8, 0x96c1b7, 0x2d673b, 0x29550d, 0x2a5709, 0x...
```

Image (1,168 samples)

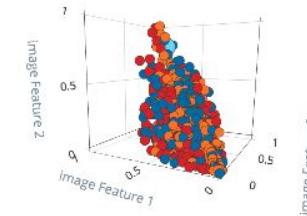
X Axis: image Feature 0
Y Axis: image Feature 1
Z Axis: image Feature 2

● angular_leaf_spot

● bean_rust

● healthy

● classification 0



Live classification - Bean Disease

studio.edgeimpulse.com/studio/51151/classification#load-sample-49581923

EDGE IMPULSE

Sample length (ms.)

Frequency: Frequency selection not supported

Start sampling

Load sample

Classification result

Summary

Name	testing.2hiofu77
Expected outcome	testing
CATEGORY	COUNT
angular_leaf_spot	0
bean_rust	1
healthy	0
uncertain	0

Detailed result

ANGULAR LEAF SPOT	BEAN RUST	HEALTHY
0	0.98	0

Show only unknowns

Bean Rusty

RAW DATA
testing.2hiofu77



Raw features

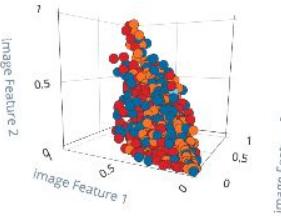
0x8c6369, 0x8a6266, 0xb666a, 0x806868, 0x55534f, 0x31413b, 0x203a34, 0x203930, 0x375c41, 0x4b9868, 0x34a469, 0x2eab6c, 0x...

Image (1,168 samples)

X Axis: image Feature 0, Y Axis: image Feature 1, Z Axis: image Feature 2

Legend:

- angular_leaf_spot
- bean_rust
- healthy
- classification 0



Processed features

0.5498, 0.3882, 0.4118, 0.5412, 0.3843, 0.4000, 0.5451, 0.4000, 0.4157, 0.5020, 0.4078, 0.4078, 0.3333, 0.3255, 0.3098, 0...

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Live classification - Bean Disease

studio.edgeimpulse.com/studio/51151/classification#load-sample-49581925

EDGE IMPULSE

Sample length (ms.)

Frequency: Frequency selection not supported

Start sampling

Load sample

Classification result

Summary

Name	testing.2hiohgsc
Expected outcome	testing
CATEGORY	COUNT
angular_leaf_spot	0
bean_rust	0
healthy	0
uncertain	1

Detailed result

ANGULAR LEAF SPOT	BEAN RUST	HEALTHY
0.03	0.47	0.49

Show only unknowns

Bean Rusty

RAW DATA
testing.2hiohgsc



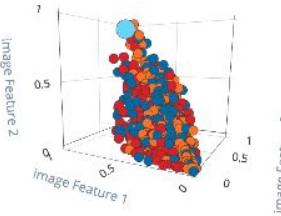
Raw features: 0x1e7f1, 0x3f617d, 0x311d26, 0x4d2e24, 0xa3022, 0xd3121, 0x513325, 0xe3423, 0x503022, 0x523021, 0x502f22, 0x523526, 0x...

Image (1,168 samples)

X Axis: image Feature 0, Y Axis: image Feature 1, Z Axis: image Feature 2

Legend:

- angular_leaf_spot (blue)
- bean_rust (orange)
- healthy (red)
- classification 0 (cyan)



Processed features: 0.7569, 0.9059, 0.9451, 0.2471, 0.3804, 0.4902, 0.1922, 0.1137, 0.1490, 0.3020, 0.1884, 0.1412, 0.2902, 0.1882, 0.1333, 0...

Live classification - Bean Disease

studio.edgeimpulse.com/studio/51151/classification#load-sample-49581926

EDGE IMPULSE

Sample length (ms.)

Frequency

Start sampling

Load sample

Classification result

Summary

Name	testing.2hiojo5d
Expected outcome	testing
CATEGORY	COUNT
angular_leaf_spot	1
bean_rust	0
healthy	0
uncertain	0

Detailed result

ANGULAR LEAF SPOT	BEAN RUST	HEALTHY
0.93	0.02	0.06

Show only unknowns

Angular Leaf Spot

RAW DATA
testing.2hiojo5d



Raw features

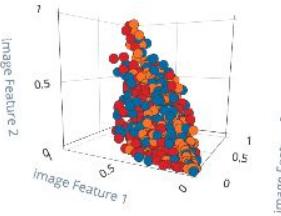
0x514b43, 0x565146, 0x535347, 0x554e44, 0x544c45, 0x534d42, 0x524a41, 0x4a473e, 0x494139, 0x4a4138, 0x50483d, 0x574f44, 0x...

Image (1,168 samples)

X Axis: image Feature 0, Y Axis: image Feature 1, Z Axis: image Feature 2

Legend:

- angular_leaf_spot (blue)
- bean_rust (orange)
- healthy (red)
- classification 0 (cyan)



Processed features

0.3176, 0.2941, 0.2627, 0.3373, 0.3176, 0.2745, 0.3255, 0.3255, 0.2784, 0.3333, 0.3059, 0.2667, 0.3294, 0.2980, 0.2786, 0...

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Live classification - Bean Disease

studio.edgeimpulse.com/studio/51151/classification#load-sample-49581928

EDGE IMPULSE

Sample length (ms.)

Frequency

Start sampling

Load sample

Classification result

Summary

Name	testing.2hiolkem
Expected outcome	testing
CATEGORY	COUNT
angular_leaf_spot	0
bean_rust	1
healthy	0
uncertain	0

Detailed result

ANGULAR LEAF SPOT	BEAN RUST	HEALTHY
0.15	0.85	0

Show only unknowns

Angular Leaf Spot

RAW DATA
testing.2hiolkem



Raw features

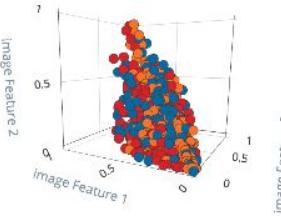
0xa26839, 0xa8693f, 0xa4633a, 0xaa6c40, 0xb37648, 0xb37345, 0xb67045, 0xb5744d, 0x7d4a2e, 0x52200d, 0x7i3a21, 0x9b5f3c, 0x...

Image (1,168 samples)

X Axis: image Feature 0, Y Axis: image Feature 1, Z Axis: image Feature 2

Legend:

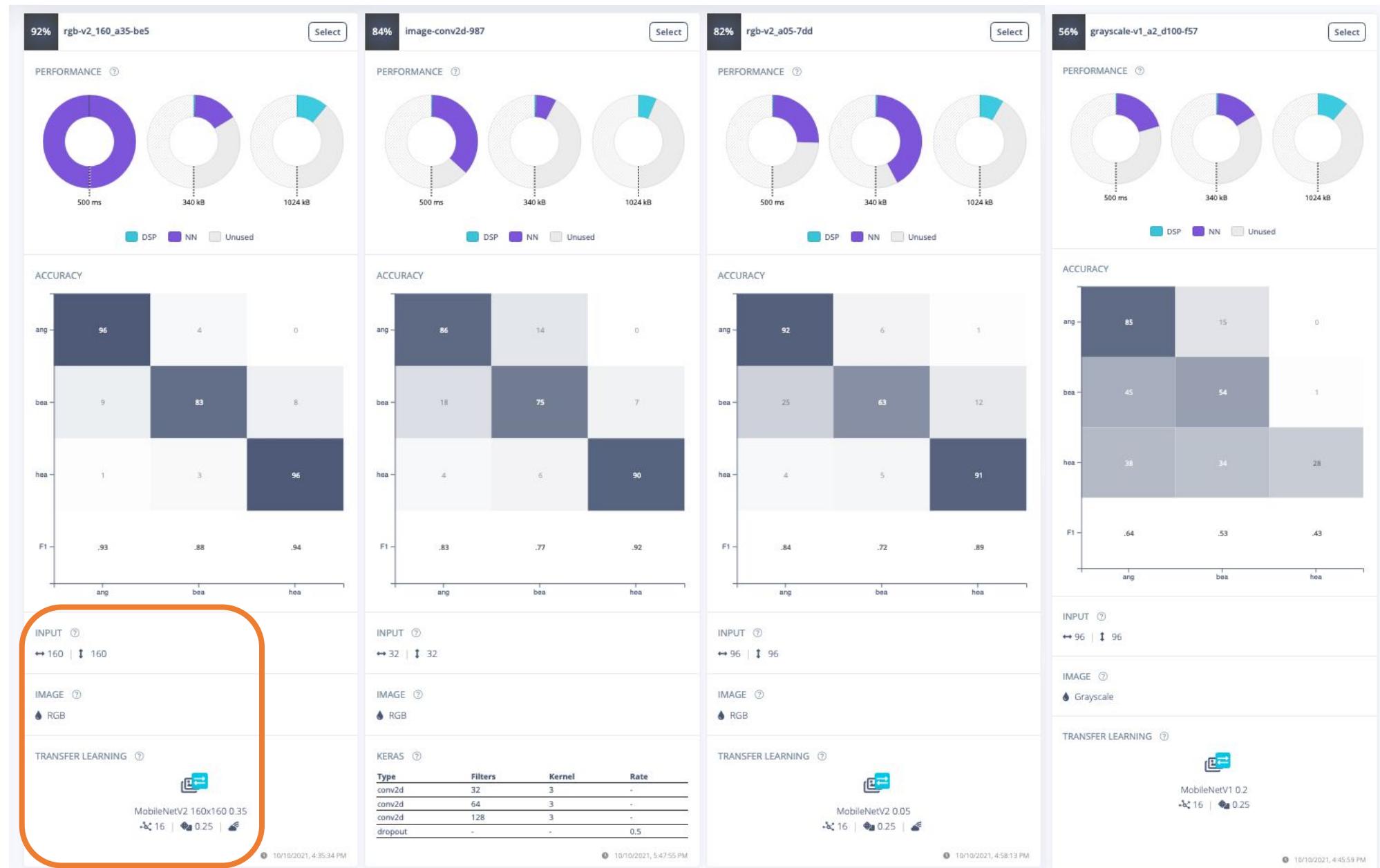
- angular_leaf_spot (blue)
- bean_rust (orange)
- healthy (red)
- classification 0 (cyan)



Processed features

0.6353, 0.4078, 0.2235, 0.6588, 0.4118, 0.2471, 0.6431, 0.3882, 0.2275, 0.6667, 0.4235, 0.2510, 0.7020, 0.4627, 0.2824, 0...

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Create impulse - Bean Disease X +

studio.edgeimpulse.com/studio/51151/create-impulse

EDGE IMPULSE CREATE IMPULSE (BEAN DISEASE CLASSIFIER)

An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

Image data

Axes

image

Image width 160 Image height 160

Resize mode Fit shortest axis

For optimal accuracy with transfer learning blocks, use a 96x96 or 160x160 image size.

Image

Name Image

Input axes image

Transfer Learning (Images)

Name Transfer Learning (Images)

Input features image

Output features 3 (angular_leaf_spot, bean_rust, healthy)

Output features

3 (angular_leaf_spot, bean_rust, healthy)

Save impulse

Add a processing block

Add a learning block

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Transfer Learning (Images) - B X +

studio.edgeimpulse.com/studio/51151/learning/keras-transfer-image/9

EDGE IMPULSE

TRANSFER LEARNING (IMAGES) (BEAN DISEASE CLASSIFIER)

#1 ▾ EON Tuner Primary

Neural Network settings

Training settings

- Number of training cycles ② 20
- Learning rate ② 0.0005
- Data augmentation ②

Neural network architecture

Input layer (76,800 features)

MobileNetV2 160x160 0.35 (final layer: 16 neurons, 0.25 dropout)

Choose a different model

Output layer (3 features)

Start training

Training output

Model Model version: ② Quantized (int8)

Last training performance (validation set)

ACCURACY 91.9% LOSS 0.23

Confusion matrix (validation set)

	ANGULAR.LEAF_SPOT	BEAN.RUST	HEALTHY
ANGULAR.LEAF_SPOT	96.2%	3.8%	0%
BEAN.RUST	9.2%	82.9%	7.9%
HEALTHY	1.3%	2.5%	96.2%
F1 SCORE	0.93	0.88	0.94

Feature explorer (full training set) ②

- angular_leaf_spot - correct
- bean_rust - correct
- healthy - correct
- angular_leaf_spot - incorrect
- bean_rust - incorrect
- healthy - incorrect

On-device performance ②

INFERENCING TIME 2,386 ms. PEAK RAM USAGE 106.6K FLASH USAGE 226.8K

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MJRoBot (Marcelo Rovai)

Model testing - Bean Disease X

studio.edgeimpulse.com/studio/51151/validation

EDGE IMPULSE

MODEL TESTING (BEAN DISEASE CLASSIFIER)

This lists all test data. You can manage this data through [Data acquisition](#).

Test data

Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse.

SAMPLE NAME	EXPECTED OUTCOME	LENGTH	ACCURACY	RESULT
testing.2hiolkem	testing	-		
testing.2hiojo5d	testing	-		
testing.2hiogsc	testing	-		
testing.2hiofu77	testing	-		
testing.2hiodaqp	testing	-		
testing.2hio9ui3	testing	-		
healthy_test.41.jpg...	healthy	-	100%	1 healthy
healthy_test.40.jpg...	healthy	-	100%	1 healthy
healthy_test.39.jpg...	healthy	-	100%	1 healthy
healthy_test.38.jpg...	healthy	-	100%	1 healthy
healthy_test.37.jpg...	healthy	-	100%	1 healthy
healthy_test.36.jpg...	healthy	-	100%	1 healthy
healthy_test.35.jpg...	healthy	-	100%	1 healthy
healthy_test.34.jpg...	healthy	-	100%	1 healthy
healthy_test.33.jpg...	healthy	-	100%	1 healthy
healthy_test.32.jpg...	healthy	-	100%	1 healthy

Model testing output

Model testing results

ACCURACY **84.38%** %

	ANGULAR_LEAF_SPOT	BEAN_RUST	HEALTHY	UNCERTAIN
ANGULAR_LEAF_SPOT	79.1%	14.0%	0%	7.0%
BEAN_RUST	7.0%	76.7%	2.3%	14.0%
HEALTHY	0%	2.4%	97.6%	0%
F1 SCORE	0.85	0.80	0.98	

Feature explorer ⓘ

- angular_leaf_spot - correct
- bean_rust - correct
- healthy - correct
- angular_leaf_spot - incorrect
- bean_rust - incorrect
- healthy - incorrect

19:22 ⓘ
Camera

AA 🔍 🔒 ne.edgeimpulse.com ⏪

Classifier



Next photo

	ANGULAR_LEAF...	BEAN_RUST	HEALTHY
2	0.01	0.02	0.97
1	0.00	0.00	1.00

< > ⌂ ⌄ ⌁

19:27 ⓘ

AA 🔍 🔒 ne.edgeimpulse.com ⏪

Classifier



Next photo

	ANGULAR_LEAF...	BEAN_RUST	HEALTHY
26	0.00	1.00	0.00
25	0.01	0.99	0.00

< > ⌂ ⌄ ⌁

19:27 ⓘ

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Classifier



Next photo

	ANGULAR_LEAF...	BEAN_RUST	HEALTHY
25	0.01	0.99	0.00
24	0.00	1.00	0.00

< > ⌂ ⌄ ⌁

19:29 ⓘ

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Classifier



Next photo

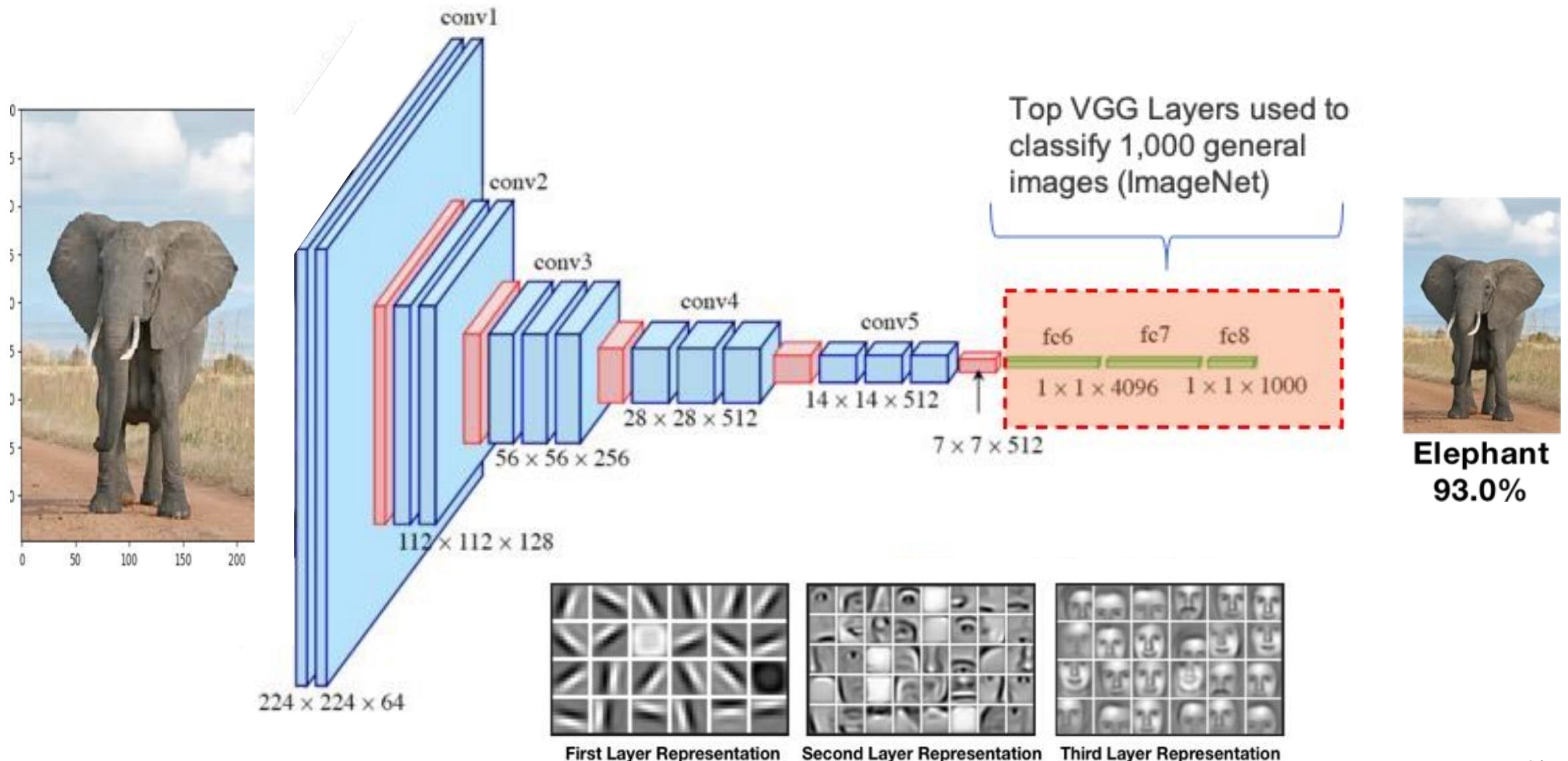
	ANGULAR_LEAF...	BEAN_RUST	HEALTHY
33	0.99	0.01	0.00
32	0.88	0.12	0.00

< > ⌂ ⌄ ⌁

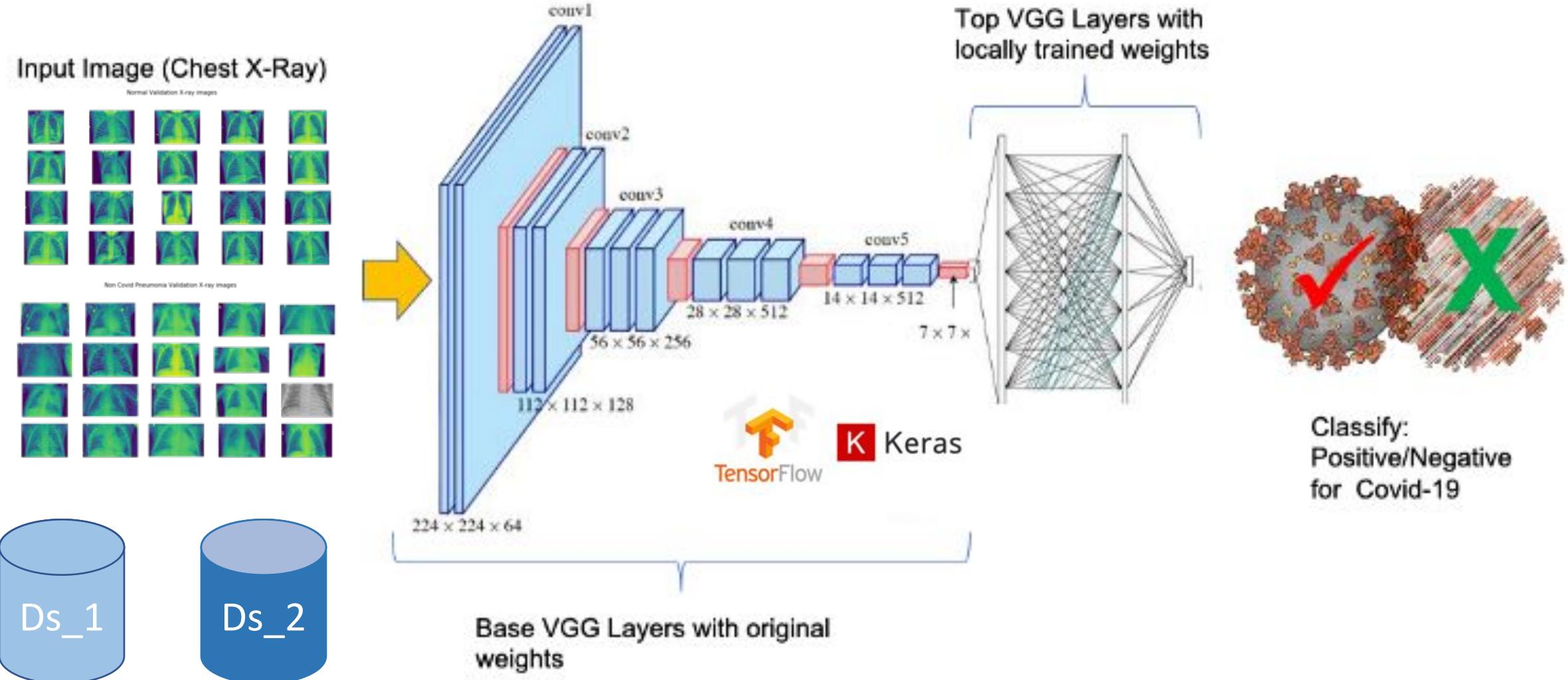
covidXray

Detecting Covid-19 in Chest X-Ray images

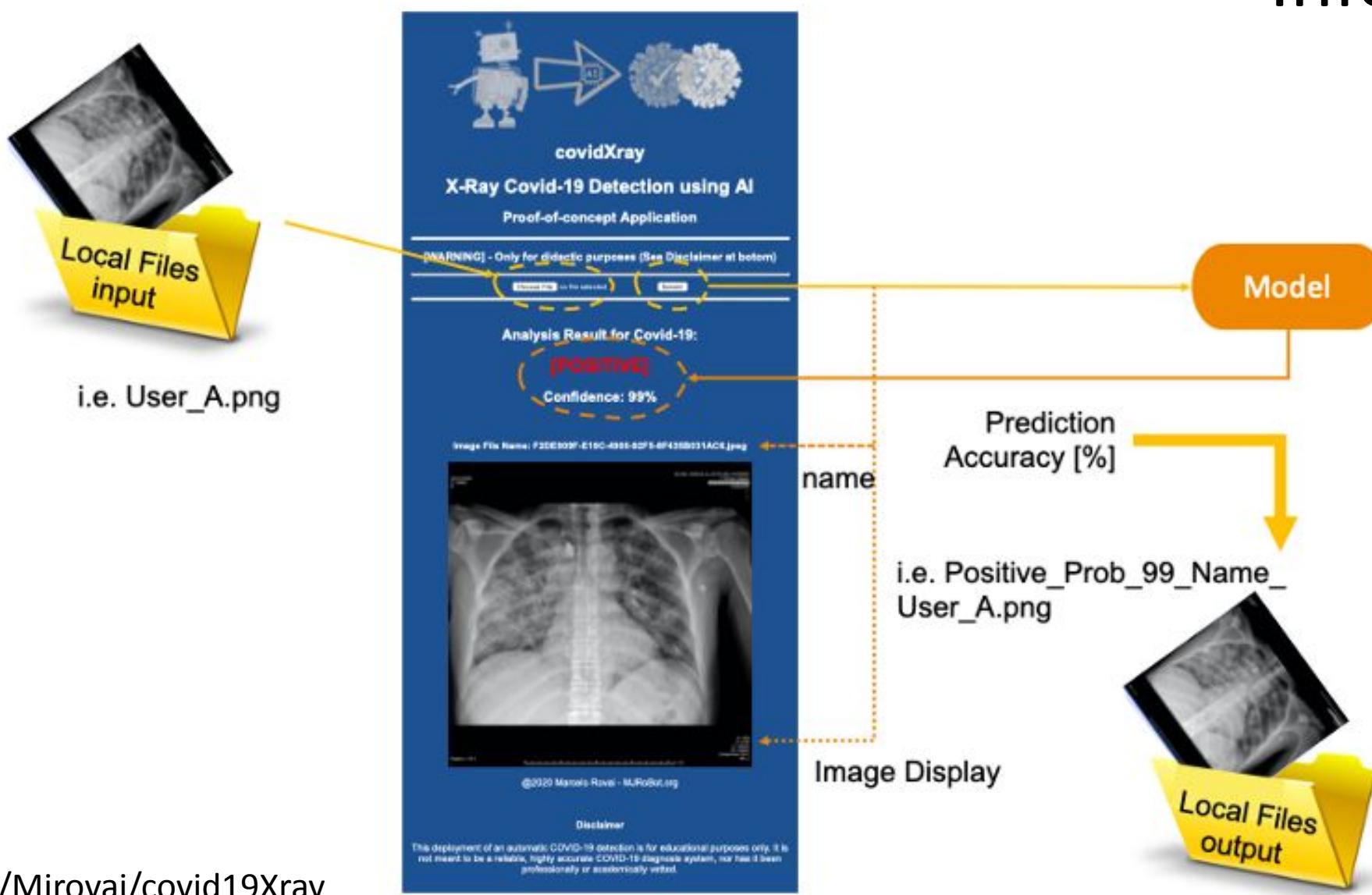
VGG-16 Convolutional Neural Network Model



Training the model (Transfer Learning)

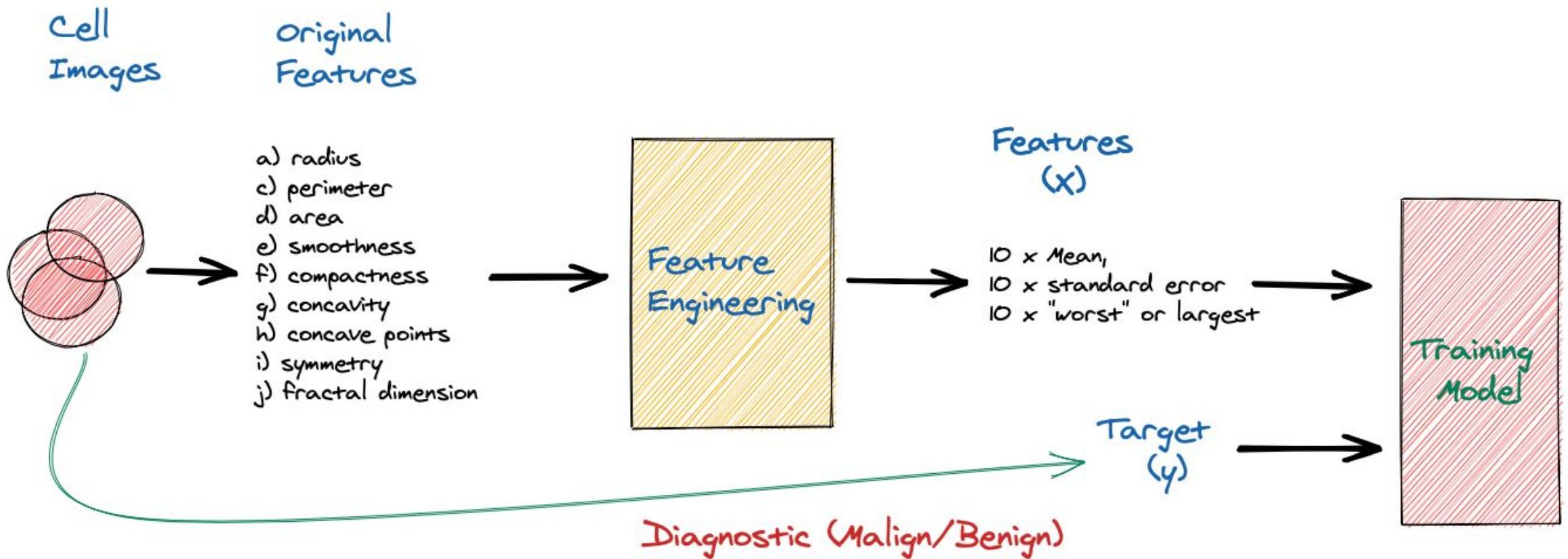


Inference



Preventing Overfitting

Early Stopping & Dropout Regularization



UCI ML Breast Cancer Wisconsin (Diagnostic) datasets. <https://goo.gl/U2Uwz2>

Wisconsin Diagnostic Breast Cancer (WDBC)

Code Time!

Breast_Cancer_Classification.ipynb



Reading Material

Main references

- [Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning](#)
- [Professional Certificate in Tiny Machine Learning \(TinyML\) – edX/Harvard](#)
- [Introduction to Embedded Machine Learning \(Coursera\)](#)
- [Text Book: "TinyML" by Pete Warden, Daniel Situnayake](#)

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The IESTI01 course is part of the TinyML4D, an initiative to make TinyML education available to everyone globally.

Thanks
And stay safe!



UNIFEI