Load Datasets

For the project, we provide a training set with 50000 images in the directory `../data/images/` with:

- noisy labels for all images provided in `../data/noisy_label.csv` ;
- clean labels for the first 10000 images provided in `../data/clean_labels.csv` .

In [35]:
```
import numpy as np
import cv2
import matplotlib.pyplot as plt
from sklearn.metrics import classification_report
from sklearn.linear_model import LogisticRegression
import time
```

In [36]:
```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
import sys
from tensorflow import keras
from keras.models import Sequential
from keras.applications.vgg16 import VGG16

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import tensorflow as tf
import cv2
from sklearn.model_selection import train_test_split

from zipfile import ZipFile
import os
import sys

sys.path.insert(0, "../lib")
#import keras.applications
from resnet import load_resnet, ResNet18
#from lossFunctions import get_custom_cross_entropy, l1_loss
```

In [ ]:
```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

In [ ]:
```
if not os.path.exists("./drive"):
    drive.mount('/content/drive')

if not os.path.exists("../data"):
    os.mkdir("../data")

# loading the temp.zip and creating a zip object
with ZipFile("./drive/MyDrive/train_data.zip", 'r') as zip_object:

    # Extracting all the members of the zip
    # into a specific location.
    zip_object.extractall(path="../data")
```

Data Preprocessing

In [ ]:
```
# [DO NOT MODIFY THIS CELL]

# load the images
n_img = 50000
n_noisy = 40000
n_clean_noisy = n_img - n_noisy
imgs = np.empty((n_img,32,32,3))
for i in range(n_img):
    #img_fn
    img_fn = f'../data/images/{i+1:05d}.png'
    #img_fn=f'/content/drive/MyDrive/ads_proj3/fall2022-project3-prj3-gro
    imgs[i,:,:,:]=cv2.cvtColor(cv2.imread(img_fn),cv2.COLOR_BGR2RGB)

# load the labels
clean_labels = np.genfromtxt('../data/clean_labels.csv', delimiter=',', d
noisy_labels = np.genfromtxt('../data/noisy_labels.csv', delimiter=',', d
```

In [ ]:

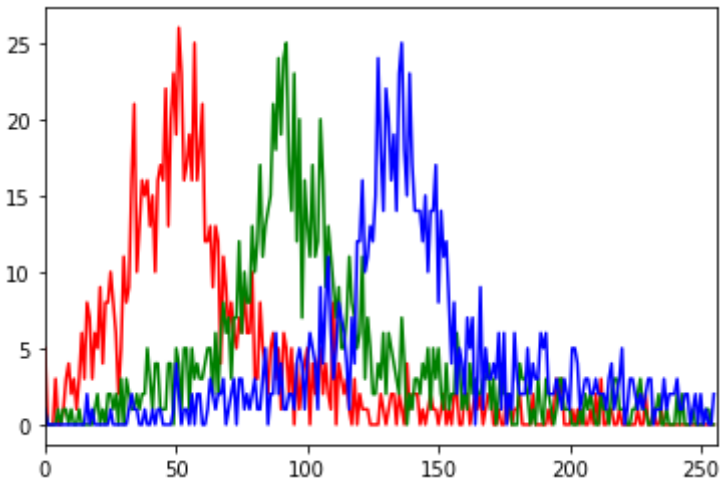
```
# example of data info
#file_path = "train_data\\images\\00001.png"
file_path="../data/images/00001.png"
img = cv2.imread(file_path)
print('Class:', type(img))
print('Dimensions:', img.shape)
print('Data Type:', img.dtype)
print('Head:', img[:3, :3])
print('Range', np.min(img), np.max(img))

color = ('r', 'g','b')
for i, col in enumerate(color):
    histr = cv2.calcHist([img],[i],None,[256],[0,256])
    plt.plot(histr,color = col)
    plt.xlim([0,256])
plt.show()
```

```
Class: <class 'numpy.ndarray'>
Dimensions: (32, 32, 3)
Data Type: uint8
Head: [[[63 62 59]
  [45 46 43]
  [43 48 50]]

 [[20 20 16]
  [ 0  0  0]
  [ 0  8 18]]

 [[21 24 25]
  [ 0  7 16]
  [ 8 27 49]]]
Range 0 255
```



In [ ]:
```
# [DO NOT MODIFY THIS CELL]

# visualize
fig = plt.figure()

ax1 = fig.add_subplot(2,4,1)
ax1.imshow(imgs[0]/255)
ax2 = fig.add_subplot(2,4,2)
ax2.imshow(imgs[1]/255)
ax3 = fig.add_subplot(2,4,3)
ax3.imshow(imgs[2]/255)
ax4 = fig.add_subplot(2,4,4)
ax4.imshow(imgs[3]/255)
ax1 = fig.add_subplot(2,4,5)
ax1.imshow(imgs[4]/255)
ax2 = fig.add_subplot(2,4,6)
ax2.imshow(imgs[5]/255)
ax3 = fig.add_subplot(2,4,7)
ax3.imshow(imgs[6]/255)
ax4 = fig.add_subplot(2,4,8)
ax4.imshow(imgs[7]/255)

# The class-label correspondence
classes = ('plane', 'car', 'bird', 'cat',
           'deer', 'dog', 'frog', 'horse', 'ship', 'truck')

# print clean labels
print('Clean labels:')
print(' '.join('%5s' % classes[clean_labels[j]] for j in range(8)))
# print noisy labels
print('Noisy labels:')
print(' '.join('%5s' % classes[noisy_labels[j]] for j in range(8)))
```

```
Clean labels:
 frog truck truck  deer   car   car  bird horse
Noisy labels:
  cat   dog truck  frog   dog  ship  bird  deer
```

Predictive Model

We consider a baseline model directly on the noisy dataset without any label corrections. RGB histogram features are extracted to fit a logistic regression model.

Baseline Model: Logistic Regression

In [ ]:
```
# [DO NOT MODIFY THIS CELL]
# RGB histogram dataset construction
no_bins = 6
bins = np.linspace(0,255,no_bins) # the range of the rgb histogram
target_vec = np.empty(n_img)
feature_mtx = np.empty((n_img,3*(len(bins)-1)))
i = 0
for i in range(n_img):
    # The target vector consists of noisy labels
    target_vec[i] = noisy_labels[i]

    # Use the numbers of pixels in each bin for all three channels as the
    feature1 = np.histogram(imgs[i][:,:,0],bins=bins)[0]
    feature2 = np.histogram(imgs[i][:,:,1],bins=bins)[0]
    feature3 = np.histogram(imgs[i][:,:,2],bins=bins)[0]

    # Concatenate three features
    feature_mtx[i,] = np.concatenate((feature1, feature2, feature3), axis=
    i += 1
```

In [ ]:
```
feature_mtx
# len(feature_mtx)
```

Out[14]:
```
array([[ 19., 102., 619., ...,  84.,  42.,  15.],
       [ 98., 301., 233., ..., 316., 200., 146.],
       [127., 405., 130., ..., 105.,  37., 306.],
       ...,
       [450., 268., 106., ..., 117.,  78., 285.],
       [ 45.,  80., 278., ..., 166., 291., 434.],
       [ 55., 193., 376., ..., 364., 150., 165.]])
```

In [ ]:
```
# [DO NOT MODIFY THIS CELL]
# Train a logistic regression model
clf = LogisticRegression(random_state=0).fit(feature_mtx, target_vec)
```

For the convenience of evaluation, we write the following function `predictive_model` that does the label prediction. **For your predictive model, feel free to modify the function, but make sure the function takes an RGB image of numpy.array format with dimension $32 \times 32 \times 3$ as input, and returns one single label as output.**

In [ ]:
```
# [DO NOT MODIFY THIS CELL]
def baseline_model(image):
    '''
    This is the baseline predictive model that takes in the image and retu
    '''
    feature1 = np.histogram(image[:,:,0],bins=bins)[0]
    feature2 = np.histogram(image[:,:,1],bins=bins)[0]
    feature3 = np.histogram(image[:,:,2],bins=bins)[0]
    feature = np.concatenate((feature1, feature2, feature3), axis=None).re
    return clf.predict(feature)
```

DATASET

In [53]:
```
# Assign Required Variables
X_train = tf.cast(imgs[10000:], dtype='float32')/255.0
y_train = tf.one_hot(noisy_labels, depth=10)
y_train_noisy=  tf.one_hot(noisy_labels[10000:], depth=10)
X_test = tf.cast(imgs[:10000], dtype='float32')/255.0
X_test_img = imgs[:10000]
y_test = tf.one_hot(clean_labels, depth = 10)
```

In [ ]:
```
aug = tf.keras.preprocessing.image.ImageDataGenerator(horizontal_flip=Tru
                                height_shift_range=0.05)
aug.fit(X_train)
```

MODEL 1

Model I: CNN

In [69]:
```
model1_cnn = keras.Sequential([
    keras.layers.Conv2D(filters=32, kernel_size=(3,3),
                        strides=1, padding='same',
                        input_shape=(32,32,3), use_bias=False),
    # keras.layers.BatchNormalization(),
    keras.layers.Activation('relu'),
    keras.layers.MaxPool2D(pool_size=(2,2), strides=2, padding='valid'),
    keras.layers.Dropout(0.2),

    keras.layers.Conv2D(filters=64, kernel_size=(3,3),
                        strides=1, padding='same', use_bias=False),
    # keras.layers.BatchNormalization(),
    keras.layers.Activation('relu'),
    keras.layers.MaxPool2D(pool_size=(2,2), strides=2, padding='valid'),
    keras.layers.Dropout(0.2),

    keras.layers.Conv2D(filters=128, kernel_size=(3,3),
                        strides=1, padding='same', use_bias=False),
    keras.layers.Activation('relu'),
    keras.layers.MaxPool2D(pool_size=(2,2), strides=2, padding='valid'),
    keras.layers.Dropout(0.2),

    keras.layers.Flatten(),
    keras.layers.Dense(64, use_bias=False),
    keras.layers.Activation('relu'),
    keras.layers.Dense(10, activation='softmax')
])
```

In [70]:
```
# categorical cross entropy due to one hot
model1_cnn.compile(optimizer = tf.keras.optimizers.Adam(0.001),
             loss = tf.keras.losses.CategoricalCrossentropy(),
             metrics = ['accuracy'])
```

In [72]:
```
%%time

early_stopping = tf.keras.callbacks.EarlyStopping(patience=10,restore_bes
mod1_cnn=model1_cnn.fit(aug.flow(X_train, y_train_noisy, batch_size = 256
```

```
Epoch 1/100
157/157 [==============================] - 17s 105ms/step - loss: 2.2537
- accuracy: 0.1769
Epoch 2/100
157/157 [==============================] - 17s 105ms/step - loss: 2.2445
- accuracy: 0.1875
Epoch 3/100
157/157 [==============================] - 17s 105ms/step - loss: 2.2322
- accuracy: 0.1992
Epoch 4/100
157/157 [==============================] - 17s 106ms/step - loss: 2.2262
- accuracy: 0.2061
Epoch 5/100
157/157 [==============================] - 17s 105ms/step - loss: 2.2152
- accuracy: 0.2160
Epoch 6/100
157/157 [==============================] - 17s 106ms/step - loss: 2.2101
- accuracy: 0.2216
Epoch 7/100
```

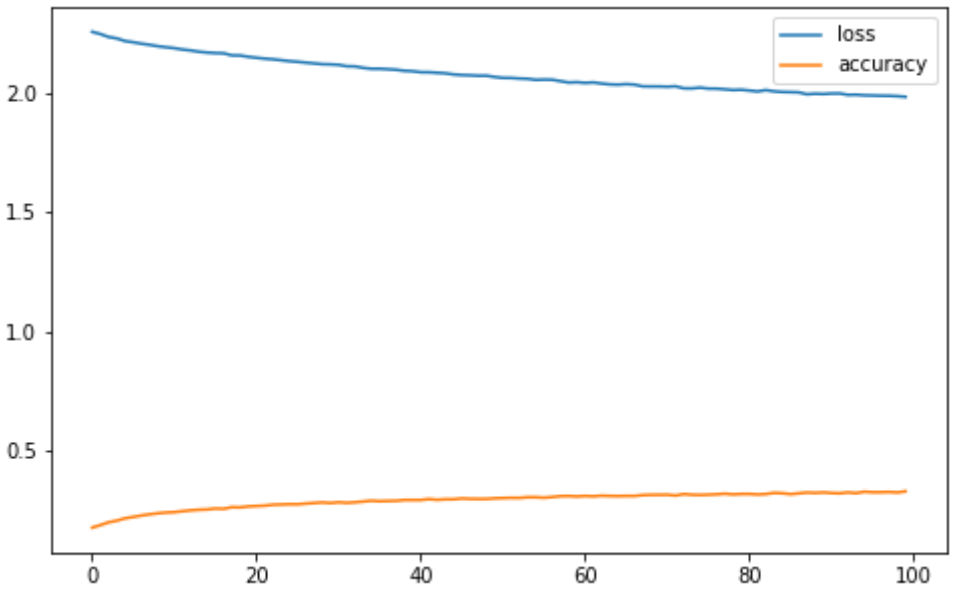
In [73]:
```
model1_cnn.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 1s 3ms/step - loss: 1.6410 - a
ccuracy: 0.5629
```

Out[73]:
```
[1.6409988403320312, 0.5629000067710876]
```

In [77]:
```
pd.DataFrame(mod1_cnn.history).plot(figsize=(8,5))
```

Out[77]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe222f57e10>
```



Model 1: VGG16

In [78]:
```
vgg = VGG16(input_shape=(32,32,3), include_top=False, weights='imagenet')
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-app
lications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5 (http
s://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weig
hts_tf_dim_ordering_tf_kernels_notop.h5)
58889256/58889256 [==============================] - 0s 0us/step
```

In [80]:
```
vgg.trainable = False
model_vgg = keras.Sequential([
    vgg,
    keras.layers.GlobalAveragePooling2D(),
    keras.layers.Dense(10, activation='softmax')
])
```

In [81]:
```
# categorical cross entropy due to one hot
model_vgg.compile(optimizer = tf.keras.optimizers.Adam(0.001),
             loss = tf.keras.losses.CategoricalCrossentropy(),
             metrics = ['accuracy'])
```

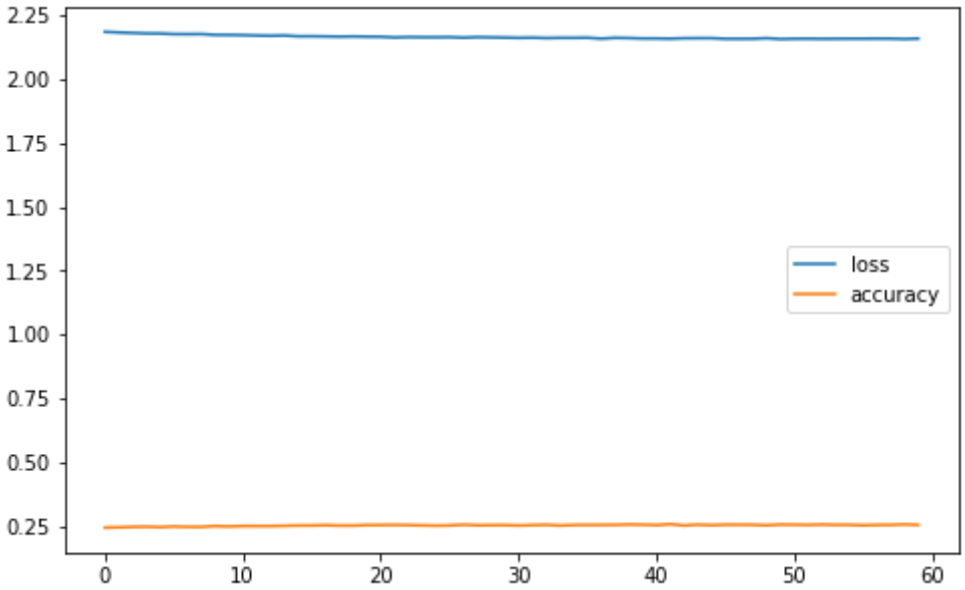
In [85]:
```
%%time

early_stopping = tf.keras.callbacks.EarlyStopping(patience=10,restore_bes
vgg_mod=model_vgg.fit(aug.flow(X_train, y_train_noisy, batch_size = 256),
```

```
Epoch 1/100
157/157 [==============================] - 18s 114ms/step - loss: 2.1856
- accuracy: 0.2439
Epoch 2/100
157/157 [==============================] - 18s 115ms/step - loss: 2.1831
- accuracy: 0.2453
Epoch 3/100
157/157 [==============================] - 18s 114ms/step - loss: 2.1813
- accuracy: 0.2468
Epoch 4/100
157/157 [==============================] - 18s 113ms/step - loss: 2.1794
- accuracy: 0.2475
Epoch 5/100
157/157 [==============================] - 18s 114ms/step - loss: 2.1791
- accuracy: 0.2462
Epoch 6/100
157/157 [==============================] - 18s 113ms/step - loss: 2.1768
- accuracy: 0.2482
Epoch 7/100
```

In [90]:
```
pd.DataFrame(vgg_mod.history).plot(figsize=(8,5))
```

Out[90]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe221cfc750>
```



In [89]:
```
model_vgg.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 4s 10ms/step - loss: 1.7533 - accuracy: 0.5252
```

Out[89]:
```
[1.7533310651779175, 0.5252000093460083]
```

In [ ]:
```

```

MODEL 1: RESNET 18

ResNet-18 is a convolutional neural network that is 18 layers deep. You can load a pretrained version of the network trained on more than a million images from the ImageNet database.

As Resnet18 does not have an equivalent version in keras. We defined resnet 18 through its architecture in resnet.py and pretrained using weights from 9000 clean labels that we have and left 1000 for testing.

In [39]:
```
from resnet import load_resnet, ResNet18
ResNet18.trainable=False
```

In [40]:
```
resnet_18=ResNet18(10)
resnet_18.build(input_shape=(None,32,32,3))
```

In [41]:
```
resnet_18.compile(loss = tf.keras.losses.CategoricalCrossentropy(),
    optimizer=tf.keras.optimizers.Adam(0.01),
    metrics=['accuracy'])
```

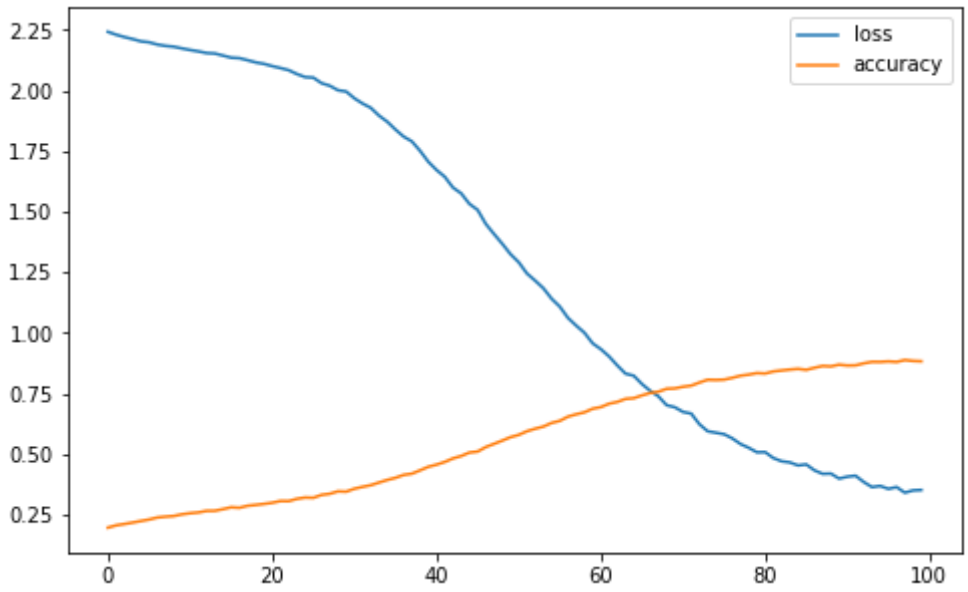
In [50]:
```
%%time
early_stopping = tf.keras.callbacks.EarlyStopping(patience=10,restore_bes

resn_model=resnet_18.fit(aug.flow(X_train, y_train_noisy, batch_size = 25
```

```
Epoch 1/100
157/157 [==============================] - 26s 163ms/step - loss: 2.2417
- accuracy: 0.1966
Epoch 2/100
157/157 [==============================] - 23s 145ms/step - loss: 2.2299
- accuracy: 0.2061
Epoch 3/100
157/157 [==============================] - 23s 149ms/step - loss: 2.2202
- accuracy: 0.2116
Epoch 4/100
157/157 [==============================] - 26s 163ms/step - loss: 2.2120
- accuracy: 0.2175
Epoch 5/100
157/157 [==============================] - 23s 149ms/step - loss: 2.2026
- accuracy: 0.2239
Epoch 6/100
157/157 [==============================] - 20s 125ms/step - loss: 2.1987
- accuracy: 0.2300
Epoch 7/100
```

In [66]:
```
pd.DataFrame(resn_model.history).plot(figsize=(8,5))
```

Out[66]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fe222298710>
```



In [58]:
```
resnet_18.evaluate(X_test,y_test)
```

```
313/313 [==============================] - 3s 10ms/step - loss: 3.6190 -
accuracy: 0.3103
```

Out[58]:
```
[3.618980884552002, 0.31029999256134033]
```

In [ ]:
```

```

EVALUATION TABLE

In [91]:
```
# import module
from tabulate import tabulate

# assign data
mydata = [
    ["CNN","0.3289","17s","0.5629"],
    ["VGG", "0.2564" ,"18s","0.5252"],
    ["Resnet-18", "0.8828","19s","0.3102"],

]

# create header
head = ["Model Name","Highest Training Accuracy", "Avg Time per epoch", "

# display table
print(tabulate(mydata, headers=head, tablefmt="grid"))
```

```
+--------------+------------------------------+----------------------+----
-------------+
| Model Name   |   Highest Training Accuracy | Avg Time per epoch   |   T
est accuracy |
+==============+==============================+======================+====
=============+
| CNN          |                       0.3289 | 17s                  |
0.5629 |
+--------------+------------------------------+----------------------+----
-------------+
| VGG          |                       0.2564 | 18s                  |
0.5252 |
+--------------+------------------------------+----------------------+----
-------------+
| Resnet-18    |                       0.8828 | 19s                  |
0.3102 |
+--------------+------------------------------+----------------------+----
-------------+
```

Conclusion

We select Resnet-18 our Model 1

In [ ]:
```

```

2.3. Model II

In [ ]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import tensorflow as tf
import cv2
from sklearn.model_selection import train_test_split

from zipfile import ZipFile
import os
import sys

# Load modules from the lib directory
sys.path.insert(0, "../lib")
from resnet import load_resnet, ResNet18
from lossFunctions import get_custom_cross_entropy, l1_loss
from model2 import LabelCleaner, ImageClassifier
```

In [ ]:
```
if not os.path.exists("./drive"):
    drive.mount('/content/drive')

if not os.path.exists("../data"):
    os.mkdir("../data")

# loading the temp.zip and creating a zip object
with ZipFile("./drive/MyDrive/train_data.zip", 'r') as zip_object:

    # Extracting all the members of the zip
    # into a specific location.
    zip_object.extractall(path="../data")
```

In [ ]:
```
# [DO NOT MODIFY THIS CELL]

n_images: int = 50_000
n_noisy: int = 40_000
n_clean: int = n_images - n_noisy

images : np.ndarray = np.empty((n_images, 32, 32, 3), dtype=np.float32)

# Load the data
for i in range(n_images):
    image_path = f"../data/images/{i+1:05d}.png"
    images[i,:,:,:] = cv2.cvtColor(cv2.imread(image_path),cv2.COLOR_BGR2RGB)

# Load the labels
clean_labels = np.genfromtxt('../data/clean_labels.csv', delimiter=',', dtype="int8")
noisy_labels = np.genfromtxt('../data/noisy_labels.csv', delimiter=',', dtype="int8")
```

In [ ]:
```
test_ratio: float = 0.2
train_size: float = n_images - (n_clean * test_ratio)
clean_noisy_ratio: float = 1 / 9
train_clean_size: int = int(np.floor(train_size * clean_noisy_ratio))
val_clean_size: int = int(np.floor((n_clean * (1 - test_ratio)) - train_clean_size))
```

```
test_clean_size: int = n_clean - train_clean_size - val_clean_size

IMG_SIZE: int = 32
IMG_SHAPE: tuple = (IMG_SIZE, IMG_SIZE, 3)

BATCH_SIZE: int = 128
```

In [ ]:
```
images_normalized = tf.cast(images, dtype = tf.float32) / 255.0
clean_labels_one_hot = tf.one_hot(clean_labels, depth = 10)
noisy_labels_one_hot = tf.one_hot(noisy_labels, depth = 10)
```

In [ ]:
```
x_clean = images_normalized[:n_clean]
y_clean = clean_labels_one_hot
x_noisy = images_normalized[n_clean:]
y_noisy = noisy_labels_one_hot
```

In [ ]:
```
x_clean_train_full, x_clean_test, y_clean_train_full, y_clean_test = train_test_split(
```

In [ ]:
```
x_clean_train, x_clean_val, y_clean_train, y_clean_val = train_test_split(x_clean_trai
```

In [ ]:
```
x_clean_train_size = len(x_clean_train)
x_clean_val_size = len(x_clean_val)
x_clean_test_size = len(x_clean_test)
```

In [ ]:
```
V = tf.data.Dataset.from_tensor_slices((
    (
        x_clean_train_full,
        noisy_labels_one_hot[:len(y_clean_train_full)]
    ),
    y_clean_train_full
))
V_test = tf.data.Dataset.from_tensor_slices((
    (
        x_clean_test,
        noisy_labels_one_hot[x_clean_train_size + x_clean_val_size:10000]
    ),
    y_clean_test
)).batch(batch_size = BATCH_SIZE)
```

In [ ]:
```
V_train = V.take(x_clean_train_size).batch(batch_size = BATCH_SIZE)
V_val = V.skip(x_clean_train_size).take(x_clean_val_size).batch(batch_size = BATCH_SIZ
del V
```

In [ ]:
```
es = tf.keras.callbacks.EarlyStopping(patience = 10, restore_best_weights = True)
```

In [ ]:
```
cnn_1 = load_resnet(10, (32, 32, 3))
cnn_1.compile(
    loss = tf.keras.losses.CategoricalCrossentropy(),
    optimizer = tf.keras.optimizers.Adam(learning_rate = 0.001),
    metrics = ["accuracy"]
)
cnn_1.trainable = False
```

In [ ]:
```
cnn_1.evaluate(x_clean_test, y_clean_test)
```

```
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is being deleted with unrestored values. See the following logs for the specific values in question. To silence these warnings, use `status.expect_partial()`. See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor details about the status object returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer.iter
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer.beta_1
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer.beta_2
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer.decay
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer.learning_rate
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).conv_1.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).init_bn.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).init_bn.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).fc.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).fc.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).res_1_1.conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).res_1_1.conv_1.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).res_1_1.bn_1.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).res_1_1.bn_1.beta
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).res_1_2.conv_1.bias
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'm' for (root).res_1_2.bn_2.gamma
```

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ot).optimizer's state 'm' for (root).res_1_2.bn_2.beta
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ot).optimizer's state 'm' for (root).res_2_1.bn_1.beta
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'm' for (root).res_2_1.bn_2.beta
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ot).optimizer's state 'm' for (root).res_2_2.bn_2.beta
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
```

```
ot).optimizer's state 'm' for (root).res_3_1.bn_2.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_3_1.res_bn.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_3_1.res_bn.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_3_2.conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_3_2.conv_1.bias
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'm' for (root).res_4_1.bn_2.beta
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_4_2.bn_1.beta
```

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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'm' for (root).res_4_2.conv_2.bias
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ot).optimizer's state 'v' for (root).fc.bias
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ot).optimizer's state 'v' for (root).res_1_1.conv_2.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_1_1.bn_2.gamma
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ot).optimizer's state 'v' for (root).res_1_1.bn_2.beta
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ot).optimizer's state 'v' for (root).res_1_2.conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_1_2.conv_1.bias
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ot).optimizer's state 'v' for (root).res_1_2.bn_1.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_1_2.bn_1.beta
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ot).optimizer's state 'v' for (root).res_1_2.conv_2.kernel
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ot).optimizer's state 'v' for (root).res_1_2.conv_2.bias
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_1_2.bn_2.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.conv_1.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
```

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ot).optimizer's state 'v' for (root).res_2_1.bn_1.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'v' for (root).res_2_1.conv_2.bias
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.bn_2.beta
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ot).optimizer's state 'v' for (root).res_2_1.res_conv.bias
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ot).optimizer's state 'v' for (root).res_2_1.res_bn.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.res_bn.beta
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ot).optimizer's state 'v' for (root).res_2_2.conv_1.kernel
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ot).optimizer's state 'v' for (root).res_2_2.conv_1.bias
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ot).optimizer's state 'v' for (root).res_2_2.bn_1.gamma
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ot).optimizer's state 'v' for (root).res_2_2.bn_1.beta
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_2.conv_2.bias
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ot).optimizer's state 'v' for (root).res_2_2.bn_2.gamma
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ot).optimizer's state 'v' for (root).res_2_2.bn_2.beta
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ot).optimizer's state 'v' for (root).res_3_1.res_conv.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_3_1.res_bn.gamma
```

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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_3_1.res_bn.beta
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ot).optimizer's state 'v' for (root).res_4_2.conv_2.bias
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ot).optimizer's state 'v' for (root).res_4_2.bn_2.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
```

```
ot).optimizer's state 'v' for (root).res_4_2.bn_2.beta
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is being
deleted with unrestored values. See the following logs for the specific values in que
stion. To silence these warnings, use `status.expect_partial()`. See https://www.tens
orflow.org/api_docs/python/tf/train/Checkpoint#restorefor details about the status ob
ject returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer.iter
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer.beta_1
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer.beta_2
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer.decay
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer.learning_rate
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).conv_1.kernel
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ot).optimizer's state 'm' for (root).conv_1.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).init_bn.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).init_bn.beta
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ot).optimizer's state 'm' for (root).fc.bias
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ot).optimizer's state 'm' for (root).res_1_1.conv_1.bias
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ot).optimizer's state 'm' for (root).res_1_1.bn_1.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_1_1.bn_1.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_1_1.conv_2.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_1_1.conv_2.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_1_1.bn_2.gamma
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ot).optimizer's state 'm' for (root).res_1_1.bn_2.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_1_2.conv_1.kernel
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ot).optimizer's state 'm' for (root).res_1_2.bn_1.beta
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ot).optimizer's state 'm' for (root).res_1_2.conv_2.kernel
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ot).optimizer's state 'm' for (root).res_1_2.conv_2.bias
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ot).optimizer's state 'm' for (root).res_1_2.bn_2.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'm' for (root).res_2_1.conv_1.bias
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ot).optimizer's state 'm' for (root).res_2_1.res_conv.bias
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ot).optimizer's state 'm' for (root).res_3_1.bn_2.gamma
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'm' for (root).res_3_1.bn_2.beta
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ot).optimizer's state 'm' for (root).res_3_1.res_bn.beta
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ot).optimizer's state 'm' for (root).res_3_2.bn_2.beta
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ot).optimizer's state 'm' for (root).res_4_1.conv_1.bias
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ot).optimizer's state 'm' for (root).res_4_1.bn_1.gamma
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ot).optimizer's state 'm' for (root).res_4_1.bn_1.beta
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ot).optimizer's state 'm' for (root).res_4_1.conv_2.kernel
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ot).optimizer's state 'm' for (root).res_4_1.conv_2.bias
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ot).optimizer's state 'm' for (root).res_4_1.bn_2.beta
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ot).optimizer's state 'm' for (root).res_4_1.res_conv.bias
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ot).optimizer's state 'm' for (root).res_4_1.res_bn.beta
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ot).optimizer's state 'm' for (root).res_4_2.bn_1.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'm' for (root).res_4_2.bn_1.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
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ot).optimizer's state 'v' for (root).fc.bias
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ot).optimizer's state 'v' for (root).res_1_1.conv_2.kernel
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ot).optimizer's state 'v' for (root).res_1_1.bn_2.gamma
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ot).optimizer's state 'v' for (root).res_1_2.bn_1.gamma
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ot).optimizer's state 'v' for (root).res_1_2.conv_2.kernel
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ot).optimizer's state 'v' for (root).res_1_2.conv_2.bias
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ot).optimizer's state 'v' for (root).res_1_2.bn_2.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.conv_1.bias
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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_2_1.bn_1.gamma
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ot).optimizer's state 'v' for (root).res_2_1.conv_2.kernel
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ot).optimizer's state 'v' for (root).res_2_1.bn_2.gamma
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ot).optimizer's state 'v' for (root).res_2_1.res_conv.kernel
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ot).optimizer's state 'v' for (root).res_2_1.res_conv.bias
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ot).optimizer's state 'v' for (root).res_2_1.res_bn.gamma
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ot).optimizer's state 'v' for (root).res_2_1.res_bn.beta
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ot).optimizer's state 'v' for (root).res_2_2.conv_1.kernel
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ot).optimizer's state 'v' for (root).res_2_2.conv_1.bias
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ot).optimizer's state 'v' for (root).res_2_2.bn_1.gamma
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ot).optimizer's state 'v' for (root).res_2_2.bn_1.beta
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ot).optimizer's state 'v' for (root).res_2_2.conv_2.kernel
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ot).optimizer's state 'v' for (root).res_2_2.conv_2.bias
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ot).optimizer's state 'v' for (root).res_2_2.bn_2.gamma
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ot).optimizer's state 'v' for (root).res_2_2.bn_2.beta
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_3_1.conv_1.kernel
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_3_1.conv_1.bias
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ot).optimizer's state 'v' for (root).res_3_1.bn_1.gamma
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ot).optimizer's state 'v' for (root).res_3_1.bn_1.beta
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ot).optimizer's state 'v' for (root).res_3_1.conv_2.kernel
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ot).optimizer's state 'v' for (root).res_3_1.bn_2.gamma
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ot).optimizer's state 'v' for (root).res_3_1.bn_2.beta
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ot).optimizer's state 'v' for (root).res_3_1.res_conv.kernel
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ot).optimizer's state 'v' for (root).res_3_1.res_conv.bias
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ot).optimizer's state 'v' for (root).res_3_1.res_bn.gamma
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_3_1.res_bn.beta
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ot).optimizer's state 'v' for (root).res_3_2.conv_1.kernel
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ot).optimizer's state 'v' for (root).res_3_2.conv_1.bias
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ot).optimizer's state 'v' for (root).res_3_2.bn_1.beta
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ot).optimizer's state 'v' for (root).res_3_2.conv_2.bias
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ot).optimizer's state 'v' for (root).res_3_2.bn_2.beta
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ot).optimizer's state 'v' for (root).res_4_1.conv_1.kernel
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ot).optimizer's state 'v' for (root).res_4_1.res_conv.kernel
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ot).optimizer's state 'v' for (root).res_4_1.res_conv.bias
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ot).optimizer's state 'v' for (root).res_4_1.res_bn.beta
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ot).optimizer's state 'v' for (root).res_4_2.conv_1.bias
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ot).optimizer's state 'v' for (root).res_4_2.bn_1.gamma
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ot).optimizer's state 'v' for (root).res_4_2.bn_1.beta
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ot).optimizer's state 'v' for (root).res_4_2.conv_2.bias
WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (ro
ot).optimizer's state 'v' for (root).res_4_2.bn_2.gamma
```

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WARNING:tensorflow:Value in checkpoint could not be found in the restored object: (root).optimizer's state 'v' for (root).res_4_2.bn_2.beta
32/32 [==============================] - 2s 10ms/step - loss: 0.3171 - accuracy: 0.9110
```

Out[ ]:
```
[0.31712672114372253, 0.9110000133514404]
```

In [ ]:
```
cnn_1.trainable = False
cleaner = LabelCleaner(cnn_1)

cleaner.compile(
    optimizer = tf.keras.optimizers.Adam(0.001),
    loss = l1_loss,
    metrics = ['accuracy']
)
```

In [ ]:
```
cleaner.fit(
    V_train,
    epochs = 60,
    validation_data = V_val,
    callbacks = [es]
)
```

```
Epoch 1/60
57/57 [==============================] - 3s 25ms/step - loss: 144.2127 - accuracy: 0.
6825 - val_loss: 147.1830 - val_accuracy: 0.5156
Epoch 2/60
57/57 [==============================] - 1s 14ms/step - loss: 40.1163 - accuracy: 0.8
618 - val_loss: 102.0742 - val_accuracy: 0.7211
Epoch 3/60
57/57 [==============================] - 1s 14ms/step - loss: 33.7128 - accuracy: 0.8
629 - val_loss: 76.0516 - val_accuracy: 0.8339
Epoch 4/60
57/57 [==============================] - 1s 14ms/step - loss: 32.9007 - accuracy: 0.8
635 - val_loss: 55.0190 - val_accuracy: 0.8639
Epoch 5/60
57/57 [==============================] - 1s 14ms/step - loss: 32.2837 - accuracy: 0.8
650 - val_loss: 41.2236 - val_accuracy: 0.8661
Epoch 6/60
57/57 [==============================] - 1s 14ms/step - loss: 31.7482 - accuracy: 0.8
664 - val_loss: 35.3415 - val_accuracy: 0.8656
Epoch 7/60
57/57 [==============================] - 1s 14ms/step - loss: 31.3158 - accuracy: 0.8
668 - val_loss: 33.2966 - val_accuracy: 0.8661
Epoch 8/60
57/57 [==============================] - 1s 14ms/step - loss: 30.9005 - accuracy: 0.8
672 - val_loss: 32.9001 - val_accuracy: 0.8656
Epoch 9/60
57/57 [==============================] - 1s 13ms/step - loss: 30.5254 - accuracy: 0.8
683 - val_loss: 33.3832 - val_accuracy: 0.8678
Epoch 10/60
57/57 [==============================] - 1s 13ms/step - loss: 30.3263 - accuracy: 0.8
687 - val_loss: 33.0628 - val_accuracy: 0.8667
Epoch 11/60
57/57 [==============================] - 1s 14ms/step - loss: 29.9822 - accuracy: 0.8
697 - val_loss: 32.6230 - val_accuracy: 0.8667
Epoch 12/60
57/57 [==============================] - 1s 13ms/step - loss: 29.8359 - accuracy: 0.8
704 - val_loss: 32.6833 - val_accuracy: 0.8667
Epoch 13/60
57/57 [==============================] - 1s 14ms/step - loss: 29.6976 - accuracy: 0.8
701 - val_loss: 32.1719 - val_accuracy: 0.8683
Epoch 14/60
57/57 [==============================] - 1s 13ms/step - loss: 29.4056 - accuracy: 0.8
703 - val_loss: 32.3488 - val_accuracy: 0.8678
Epoch 15/60
57/57 [==============================] - 1s 14ms/step - loss: 29.2821 - accuracy: 0.8
718 - val_loss: 32.0218 - val_accuracy: 0.8694
Epoch 16/60
57/57 [==============================] - 1s 14ms/step - loss: 29.1975 - accuracy: 0.8
711 - val_loss: 31.6924 - val_accuracy: 0.8689
Epoch 17/60
57/57 [==============================] - 1s 13ms/step - loss: 29.1457 - accuracy: 0.8
714 - val_loss: 31.7353 - val_accuracy: 0.8683
Epoch 18/60
57/57 [==============================] - 1s 14ms/step - loss: 28.8578 - accuracy: 0.8
721 - val_loss: 31.6458 - val_accuracy: 0.8700
Epoch 19/60
57/57 [==============================] - 1s 13ms/step - loss: 28.6731 - accuracy: 0.8
729 - val_loss: 31.8186 - val_accuracy: 0.8689
```

```
Epoch 20/60
57/57 [==============================] - 1s 14ms/step - loss: 28.5593 - accuracy: 0.8
731 - val_loss: 31.6456 - val_accuracy: 0.8700
Epoch 21/60
57/57 [==============================] - 1s 13ms/step - loss: 28.5263 - accuracy: 0.8
740 - val_loss: 31.9543 - val_accuracy: 0.8683
Epoch 22/60
57/57 [==============================] - 1s 13ms/step - loss: 28.4680 - accuracy: 0.8
732 - val_loss: 31.6660 - val_accuracy: 0.8678
Epoch 23/60
57/57 [==============================] - 1s 13ms/step - loss: 28.1531 - accuracy: 0.8
754 - val_loss: 31.8029 - val_accuracy: 0.8706
Epoch 24/60
57/57 [==============================] - 1s 14ms/step - loss: 28.3030 - accuracy: 0.8
740 - val_loss: 31.6323 - val_accuracy: 0.8689
Epoch 25/60
57/57 [==============================] - 1s 14ms/step - loss: 28.2648 - accuracy: 0.8
765 - val_loss: 31.3427 - val_accuracy: 0.8694
Epoch 26/60
57/57 [==============================] - 1s 13ms/step - loss: 28.0794 - accuracy: 0.8
754 - val_loss: 31.4929 - val_accuracy: 0.8711
Epoch 27/60
57/57 [==============================] - 1s 13ms/step - loss: 28.0483 - accuracy: 0.8
763 - val_loss: 31.4669 - val_accuracy: 0.8717
Epoch 28/60
57/57 [==============================] - 1s 13ms/step - loss: 27.9692 - accuracy: 0.8
765 - val_loss: 31.4872 - val_accuracy: 0.8711
Epoch 29/60
57/57 [==============================] - 1s 13ms/step - loss: 27.9077 - accuracy: 0.8
761 - val_loss: 31.3515 - val_accuracy: 0.8728
Epoch 30/60
57/57 [==============================] - 1s 13ms/step - loss: 27.6583 - accuracy: 0.8
776 - val_loss: 31.5206 - val_accuracy: 0.8706
Epoch 31/60
57/57 [==============================] - 1s 14ms/step - loss: 26.9778 - accuracy: 0.8
825 - val_loss: 29.8108 - val_accuracy: 0.8839
Epoch 32/60
57/57 [==============================] - 1s 13ms/step - loss: 26.7351 - accuracy: 0.8
863 - val_loss: 29.9785 - val_accuracy: 0.8822
Epoch 33/60
57/57 [==============================] - 1s 14ms/step - loss: 26.4671 - accuracy: 0.8
868 - val_loss: 29.3014 - val_accuracy: 0.8961
Epoch 34/60
57/57 [==============================] - 1s 14ms/step - loss: 18.5209 - accuracy: 0.9
325 - val_loss: 18.5981 - val_accuracy: 0.9278
Epoch 35/60
57/57 [==============================] - 1s 14ms/step - loss: 16.0708 - accuracy: 0.9
381 - val_loss: 18.2304 - val_accuracy: 0.9294
Epoch 36/60
57/57 [==============================] - 1s 13ms/step - loss: 15.6734 - accuracy: 0.9
396 - val_loss: 18.2561 - val_accuracy: 0.9272
Epoch 37/60
57/57 [==============================] - 1s 13ms/step - loss: 15.7077 - accuracy: 0.9
397 - val_loss: 18.4675 - val_accuracy: 0.9283
Epoch 38/60
57/57 [==============================] - 1s 13ms/step - loss: 15.5144 - accuracy: 0.9
400 - val_loss: 18.3966 - val_accuracy: 0.9267
```

```
Epoch 39/60
57/57 [==============================] - 1s 13ms/step - loss: 15.4156 - accuracy: 0.9
401 - val_loss: 18.2500 - val_accuracy: 0.9267
Epoch 40/60
57/57 [==============================] - 1s 14ms/step - loss: 15.3753 - accuracy: 0.9
404 - val_loss: 18.1604 - val_accuracy: 0.9278
Epoch 41/60
57/57 [==============================] - 1s 13ms/step - loss: 15.2652 - accuracy: 0.9
413 - val_loss: 18.4661 - val_accuracy: 0.9244
Epoch 42/60
57/57 [==============================] - 1s 13ms/step - loss: 15.2784 - accuracy: 0.9
401 - val_loss: 18.4473 - val_accuracy: 0.9244
Epoch 43/60
57/57 [==============================] - 1s 13ms/step - loss: 15.1652 - accuracy: 0.9
410 - val_loss: 18.3328 - val_accuracy: 0.9261
Epoch 44/60
57/57 [==============================] - 1s 13ms/step - loss: 15.1593 - accuracy: 0.9
413 - val_loss: 18.9192 - val_accuracy: 0.9261
Epoch 45/60
57/57 [==============================] - 1s 13ms/step - loss: 15.0368 - accuracy: 0.9
424 - val_loss: 18.3384 - val_accuracy: 0.9272
Epoch 46/60
57/57 [==============================] - 1s 13ms/step - loss: 15.0386 - accuracy: 0.9
413 - val_loss: 18.2480 - val_accuracy: 0.9278
Epoch 47/60
57/57 [==============================] - 1s 13ms/step - loss: 14.8684 - accuracy: 0.9
417 - val_loss: 18.3713 - val_accuracy: 0.9261
Epoch 48/60
57/57 [==============================] - 1s 14ms/step - loss: 14.9243 - accuracy: 0.9
414 - val_loss: 17.9589 - val_accuracy: 0.9300
Epoch 49/60
57/57 [==============================] - 1s 13ms/step - loss: 14.8779 - accuracy: 0.9
411 - val_loss: 18.3441 - val_accuracy: 0.9261
Epoch 50/60
57/57 [==============================] - 1s 14ms/step - loss: 14.9845 - accuracy: 0.9
419 - val_loss: 17.9183 - val_accuracy: 0.9294
Epoch 51/60
57/57 [==============================] - 1s 13ms/step - loss: 14.6604 - accuracy: 0.9
422 - val_loss: 18.1177 - val_accuracy: 0.9272
Epoch 52/60
57/57 [==============================] - 1s 13ms/step - loss: 14.7114 - accuracy: 0.9
421 - val_loss: 18.1657 - val_accuracy: 0.9272
Epoch 53/60
57/57 [==============================] - 1s 13ms/step - loss: 14.6706 - accuracy: 0.9
428 - val_loss: 18.3589 - val_accuracy: 0.9272
Epoch 54/60
57/57 [==============================] - 1s 13ms/step - loss: 14.5373 - accuracy: 0.9
431 - val_loss: 18.0170 - val_accuracy: 0.9294
Epoch 55/60
57/57 [==============================] - 1s 13ms/step - loss: 14.5484 - accuracy: 0.9
429 - val_loss: 17.9400 - val_accuracy: 0.9272
Epoch 56/60
57/57 [==============================] - 1s 13ms/step - loss: 14.7120 - accuracy: 0.9
426 - val_loss: 18.0593 - val_accuracy: 0.9283
Epoch 57/60
57/57 [==============================] - 1s 13ms/step - loss: 14.6741 - accuracy: 0.9
428 - val_loss: 17.9750 - val_accuracy: 0.9300
```

```
Epoch 58/60
57/57 [==============================] - 1s 13ms/step - loss: 14.5798 - accuracy: 0.9
425 - val_loss: 18.2836 - val_accuracy: 0.9289
Epoch 59/60
57/57 [==============================] - 1s 13ms/step - loss: 14.5435 - accuracy: 0.9
432 - val_loss: 18.0208 - val_accuracy: 0.9278
Epoch 60/60
57/57 [==============================] - 1s 14ms/step - loss: 14.4863 - accuracy: 0.9
436 - val_loss: 18.0674 - val_accuracy: 0.9317
```

Out[ ]:
```
<keras.callbacks.History at 0x7f08fae76ad0>
```

In [ ]:
```
cleaner.evaluate(V_test)
cleaner.trainable = False
```

```
8/8 [==============================] - 0s 18ms/step - loss: 18.5810 - accuracy: 0.923
0
```

In [ ]:
```
c_train_full = tf.nn.softmax(
    cleaner.predict([
        images_normalized,
        y_noisy
    ])
)
```

```
1563/1563 [==============================] - 10s 6ms/step
```

In [ ]:
```
cnn_1.trainable = False
# image_classifier = tf.keras.Sequential([
#     cnn_1,
#     tf.keras.layers.Dense(units = 512),
#     tf.keras.layers.Dense(units = 10, activation = "sigmoid")
# ])
image_classifier = ImageClassifier(cnn_1)

image_classifier.compile(
    loss = tf.keras.losses.CategoricalCrossentropy(),
    optimizer = tf.keras.optimizers.Adam(0.001),
    metrics = ['accuracy']
)
```

In [ ]:
```
def ImageClassifier(cnn: tf.keras.Model) -> tf.keras.Model:
    """
    Build a new model that takes images as input and outputs class probabilities.

    Parameters:
    -----------

    `cnn: tf.keras.Model`
        The base CNN model to use.

    `return`
        The new model.
    """
    return tf.keras.Sequential([
        cnn,
        tf.keras.layers.Dense(units = 64),
```

```
        tf.keras.layers.Dense(units = 10, activation = "sigmoid")
    ])
```

In [ ]:

```
image_classifier.fit(
    images_normalized,
    c_train_full,
    epochs = 30,
    batch_size = BATCH_SIZE,
)
```

```
Epoch 1/30
391/391 [==============================] - 6s 11ms/step - loss: 2.2450 - accuracy: 0.
8976
Epoch 2/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9390
Epoch 3/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9390
Epoch 4/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9394
Epoch 5/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9393
Epoch 6/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9390
Epoch 7/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 8/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 9/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9389
Epoch 10/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 11/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 12/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 13/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 14/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 15/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 16/30
391/391 [==============================] - 4s 11ms/step - loss: 2.2386 - accuracy: 0.
9390
Epoch 17/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9389
Epoch 18/30
391/391 [==============================] - 4s 11ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 19/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9393
```

```
Epoch 20/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 21/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 22/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 23/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9393
Epoch 24/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9393
Epoch 25/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 26/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9392
Epoch 27/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9390
Epoch 28/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9391
Epoch 29/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9394
Epoch 30/30
391/391 [==============================] - 4s 10ms/step - loss: 2.2386 - accuracy: 0.
9394
```

Out[ ]:
```
<keras.callbacks.History at 0x7f07efb1efd0>
```

In [ ]:
```
image_classifier.fit(
    x_clean_train,
    y_clean_train,
    epochs = 30,
    batch_size = BATCH_SIZE,
    validation_data = (x_clean_val, y_clean_val),
    callbacks = [es]
)
```

```
Epoch 1/30
57/57 [==============================] - 1s 25ms/step - loss: 0.5831 - accuracy: 0.92
44 - val_loss: 0.3229 - val_accuracy: 0.9222
Epoch 2/30
57/57 [==============================] - 1s 13ms/step - loss: 0.3031 - accuracy: 0.92
76 - val_loss: 0.3202 - val_accuracy: 0.9217
Epoch 3/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2979 - accuracy: 0.92
81 - val_loss: 0.3195 - val_accuracy: 0.9228
Epoch 4/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2960 - accuracy: 0.92
82 - val_loss: 0.3192 - val_accuracy: 0.9211
Epoch 5/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2949 - accuracy: 0.92
90 - val_loss: 0.3185 - val_accuracy: 0.9222
Epoch 6/30
57/57 [==============================] - 1s 12ms/step - loss: 0.2939 - accuracy: 0.92
87 - val_loss: 0.3192 - val_accuracy: 0.9222
Epoch 7/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2931 - accuracy: 0.92
85 - val_loss: 0.3201 - val_accuracy: 0.9222
Epoch 8/30
57/57 [==============================] - 1s 12ms/step - loss: 0.2925 - accuracy: 0.92
93 - val_loss: 0.3197 - val_accuracy: 0.9222
Epoch 9/30
57/57 [==============================] - 1s 12ms/step - loss: 0.2921 - accuracy: 0.92
97 - val_loss: 0.3205 - val_accuracy: 0.9222
Epoch 10/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2915 - accuracy: 0.92
97 - val_loss: 0.3204 - val_accuracy: 0.9217
Epoch 11/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2914 - accuracy: 0.92
90 - val_loss: 0.3205 - val_accuracy: 0.9211
Epoch 12/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2911 - accuracy: 0.93
06 - val_loss: 0.3202 - val_accuracy: 0.9217
Epoch 13/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2912 - accuracy: 0.92
96 - val_loss: 0.3209 - val_accuracy: 0.9222
Epoch 14/30
57/57 [==============================] - 1s 12ms/step - loss: 0.2909 - accuracy: 0.92
90 - val_loss: 0.3204 - val_accuracy: 0.9228
Epoch 15/30
57/57 [==============================] - 1s 13ms/step - loss: 0.2907 - accuracy: 0.93
03 - val_loss: 0.3206 - val_accuracy: 0.9228
```

Out[ ]:
```
<keras.callbacks.History at 0x7f07ef8b9650>
```

In [ ]:
```
image_classifier.evaluate(images_normalized, c_train_full)
```

```
1563/1563 [==============================] - 12s 8ms/step - loss: 4.3865 - accuracy:
0.9573
```

Out[ ]:
```
[4.386488914489746, 0.9573400020599365]
```

In [ ]:
```
image_classifier.save_weights("data/image_classifier/image_classifier")
```

In [ ]:
```
# [ADD WEAKLY SUPERVISED LEARNING FEATURE TO MODEL I]
```

```python
# write your code here...

def model_II(image):
    '''
    This function should takes in the image of dimension 32*32*3 as input and returns
    '''
    # write your code here...
    image_classifier.load_weights("data/image_classifier/image_classifier")


    pred = image_classifier(image.numpy().reshape(1, 32, 32, 3))
    label = int(tf.argmax(pred, 1))

    return label
```