Model_Scratch 01 - Data augmentation

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Validation dataset: train5

Directories

This section sets up the directory paths used for training, validation, and test datasets based on the repository structure.

In [ ]:
```
import os

current_dir = os.getcwd()

# TWO FOLDERS UP
data_dir = os.path.abspath(os.path.join(current_dir, os.pardir, os.pardir
test_dir = os.path.join(data_dir, 'test')
train_dir = os.path.join(data_dir, 'train')

train_dirs = []
for i in range(1, 5):
    train_dirs.append(os.path.join(train_dir, 'train' + str(i)))

validation_dir = os.path.join(data_dir, 'train', 'train5')

print(current_dir)
print(data_dir)
print(test_dir)
print(train_dir)
print(validation_dir)
```

```
/home/pws/code/IA-image-classification/notebooks/models-S
/home/pws/code/IA-image-classification/data
/home/pws/code/IA-image-classification/data/test
/home/pws/code/IA-image-classification/data/train
/home/pws/code/IA-image-classification/data/train/train5
```

Preprocessing

Load the datasets and perform initial preprocessing. Images are resized to 32x32 pixels and batched.

In [ ]:
```
from keras.utils import image_dataset_from_directory
import tensorflow as tf

# Load training datasets from train1 to train4
train_datasets = []
IMG_SIZE = 32
BATCH_SIZE = 64
```

```
for i in range(1, 5):
    dataset = image_dataset_from_directory(train_dirs[i-1], image_size=(I
    train_datasets.append(dataset)

train_dataset = train_datasets[0]
for dataset in train_datasets[1:]:
    train_dataset = train_dataset.concatenate(dataset)

validation_dataset = image_dataset_from_directory(validation_dir, image_s

test_dataset = image_dataset_from_directory(test_dir, image_size=(IMG_SIZ

class_names = validation_dataset.class_names
class_names = [class_name.split('_')[-1] for class_name in class_names]

print(class_names)
```

```
2024-06-22 20:44:22.995748: E external/local_xla/xla/stream_executor/cuda/
cuda_dnn.cc:9261] Unable to register cuDNN factory: Attempting to register
factory for plugin cuDNN when one has already been registered
2024-06-22 20:44:22.995780: E external/local_xla/xla/stream_executor/cuda/
cuda_fft.cc:607] Unable to register cuFFT factory: Attempting to register
factory for plugin cuFFT when one has already been registered
2024-06-22 20:44:22.996801: E external/local_xla/xla/stream_executor/cuda/
cuda_blas.cc:1515] Unable to register cuBLAS factory: Attempting to regist
er factory for plugin cuBLAS when one has already been registered
2024-06-22 20:44:23.002659: I tensorflow/core/platform/cpu_feature_guard.c
c:182] This TensorFlow binary is optimized to use available CPU instructio
ns in performance-critical operations.
To enable the following instructions: AVX2 FMA, in other operations, rebui
ld TensorFlow with the appropriate compiler flags.
2024-06-22 20:44:24.090481: W tensorflow/compiler/tf2tensorrt/utils/py_uti
ls.cc:38] TF-TRT Warning: Could not find TensorRT
Found 10000 files belonging to 10 classes.
```

```
2024-06-22 20:44:25.464478: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.496996: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.497164: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.497675: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.497802: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.497931: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.565144: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.565298: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.565427: I external/local_xla/xla/stream_executor/cuda/
cuda_executor.cc:901] successful NUMA node read from SysFS had negative va
lue (-1), but there must be at least one NUMA node, so returning NUMA node
zero. See more at https://github.com/torvalds/linux/blob/v6.0/Documentatio
n/ABI/testing/sysfs-bus-pci#L344-L355
2024-06-22 20:44:25.565525: I tensorflow/core/common_runtime/gpu/gpu_devic
e.cc:1929] Created device /job:localhost/replica:0/task:0/device:GPU:0 wit
h 299 MB memory:  -> device: 0, name: NVIDIA GeForce GTX 1060 6GB, pci bus
id: 0000:01:00.0, compute capability: 6.1
Found 10000 files belonging to 10 classes.
Found 10000 files belonging to 10 classes.
Found 10000 files belonging to 10 classes.
Found 10000 files belonging to 10 classes.
Found 10000 files belonging to 10 classes.
['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse',
'ship', 'truck']
```

Configure the dataset for performance

In [ ]:
```
AUTOTUNE = tf.data.AUTOTUNE

train_dataset = train_dataset.cache().shuffle(1000).prefetch(buffer_size=
validation_dataset = validation_dataset.cache().prefetch(buffer_size=AUTO
test_dataset = test_dataset.cache().prefetch(buffer_size=AUTOTUNE)
```

Data Augmentation

Rendom change of flipping the image horizontally.
Random chance of moving the image horizontally and vertically [-10%, 10%].

Tried with a more complex approach to data augmentation, but the results were worse because of the small size of the images.

In [ ]:
```
from keras import layers

data_augmentation = tf.keras.Sequential([
    layers.RandomFlip("horizontal"),
    layers.RandomTranslation(0.1, 0.1, fill_mode='nearest'),
])
```

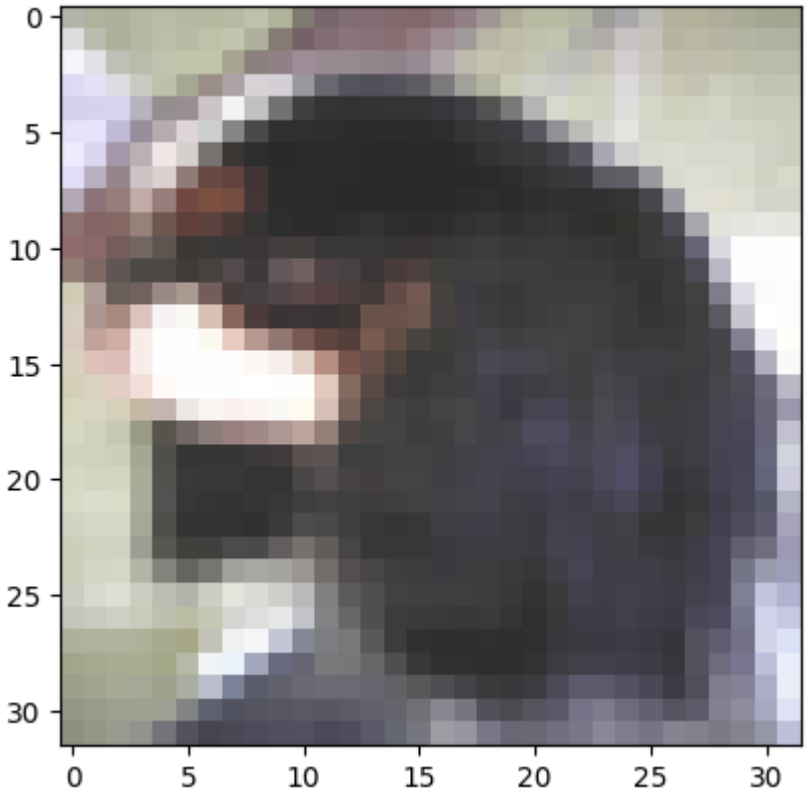
In [ ]:
```
import matplotlib.pyplot as plt
import numpy as np

#Plot some Augmented images
for images, labels in train_dataset.take(1):
    plt.figure(figsize=(10, 10))
    first_image = images[0]
    for i in range(4):
        ax = plt.subplot(2, 2, i + 1)
        augmented_image = data_augmentation(tf.expand_dims(first_image, 0
        plt.imshow(augmented_image[0] / 255)
        plt.axis('off')
```




In [ ]:
```
import matplotlib.pyplot as plt

for data, _ in train_dataset.take(1):
    for i in range(9):
        plt.imshow(data[i].numpy().astype('uint8'))
        plt.show()
    break
```


0
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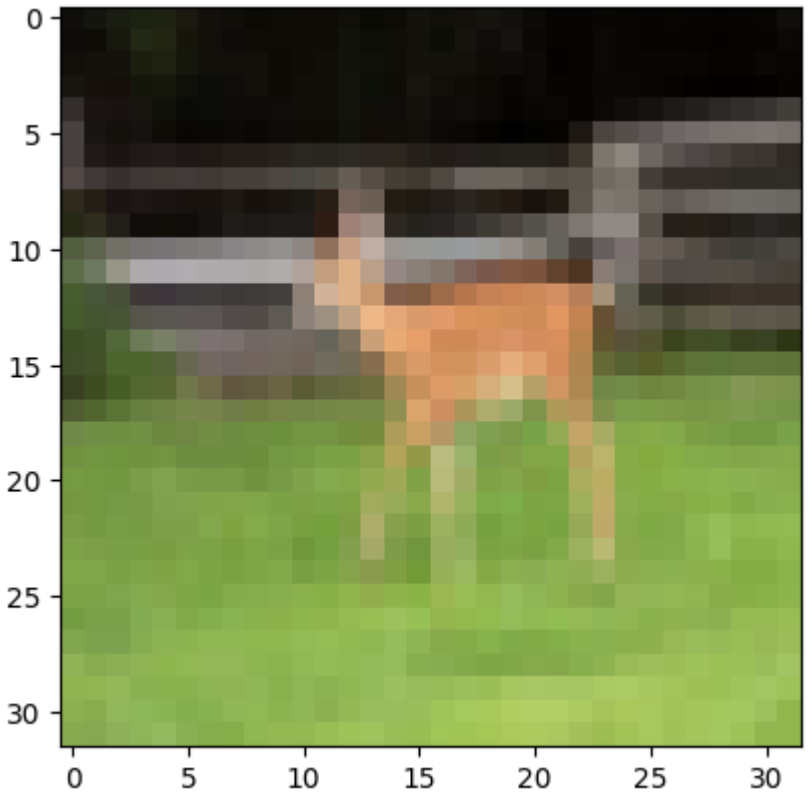
30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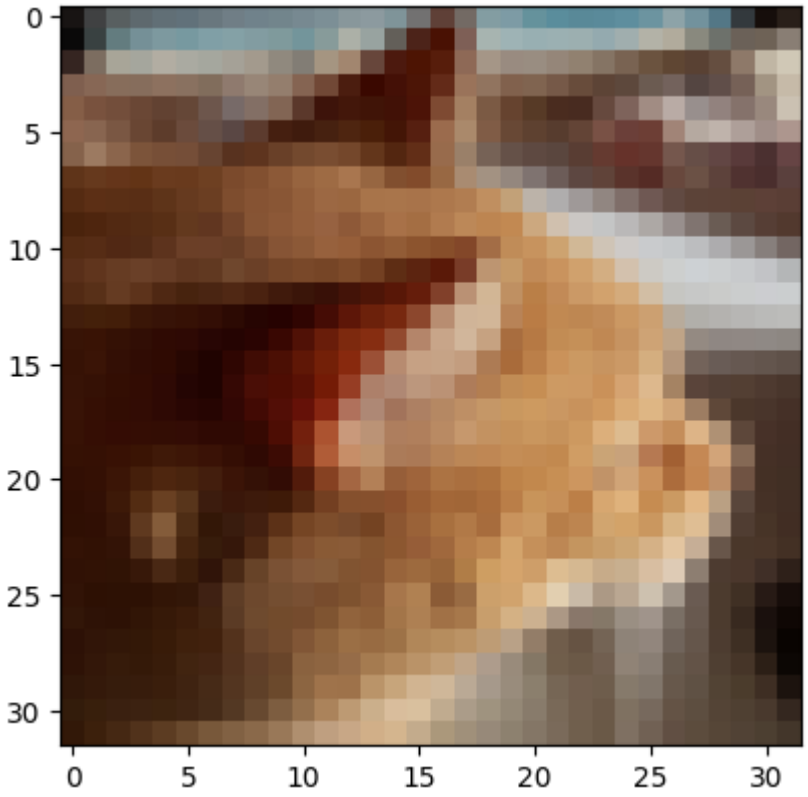
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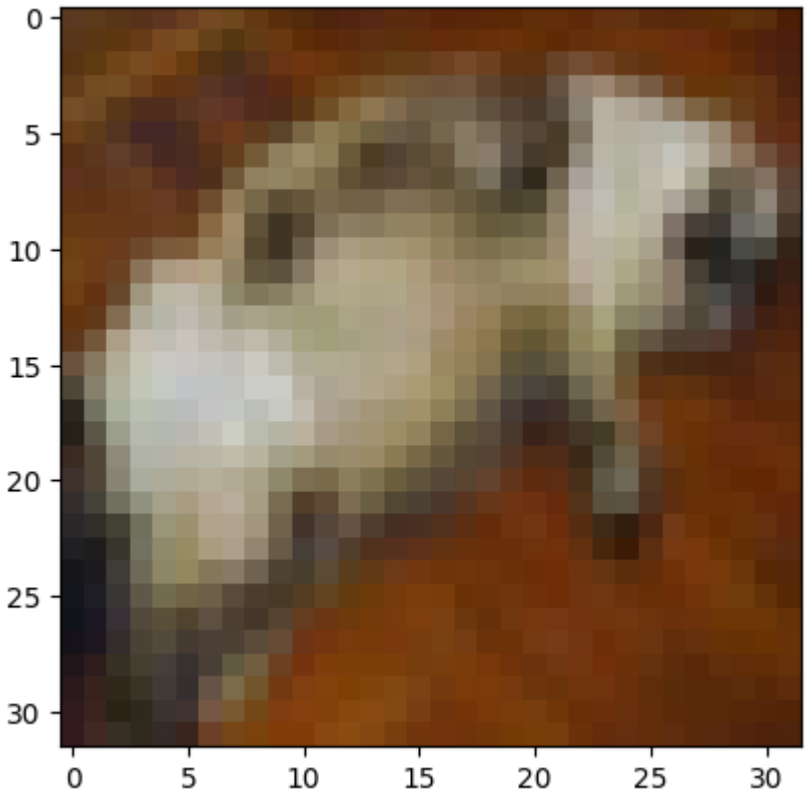
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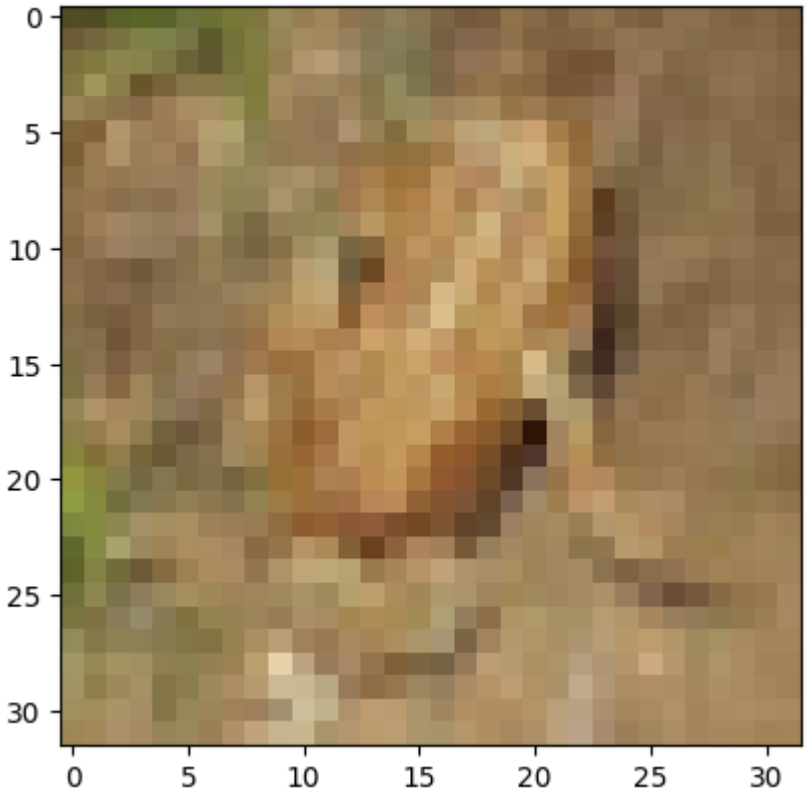
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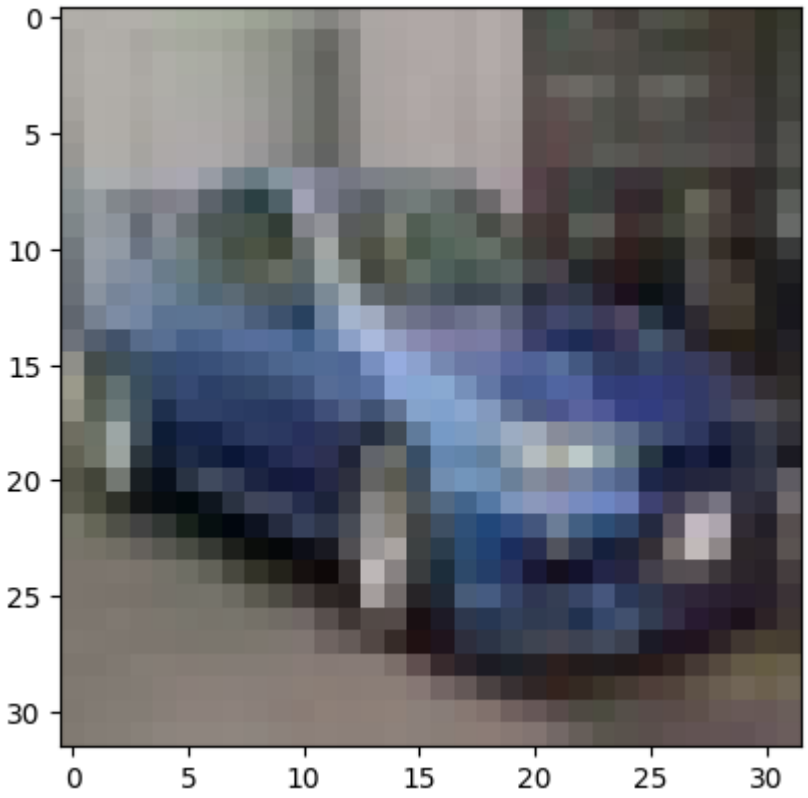
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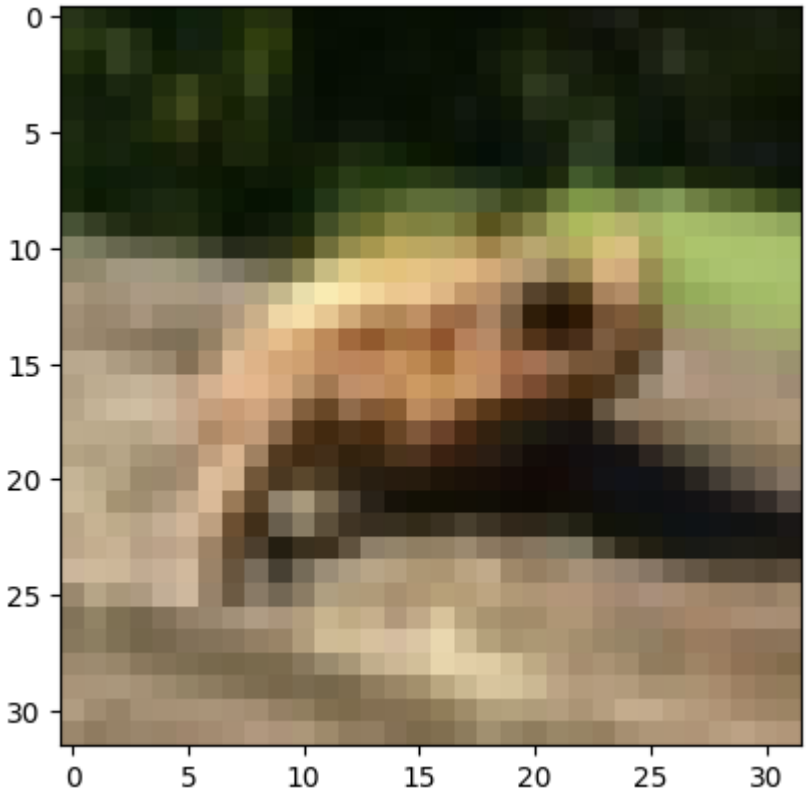
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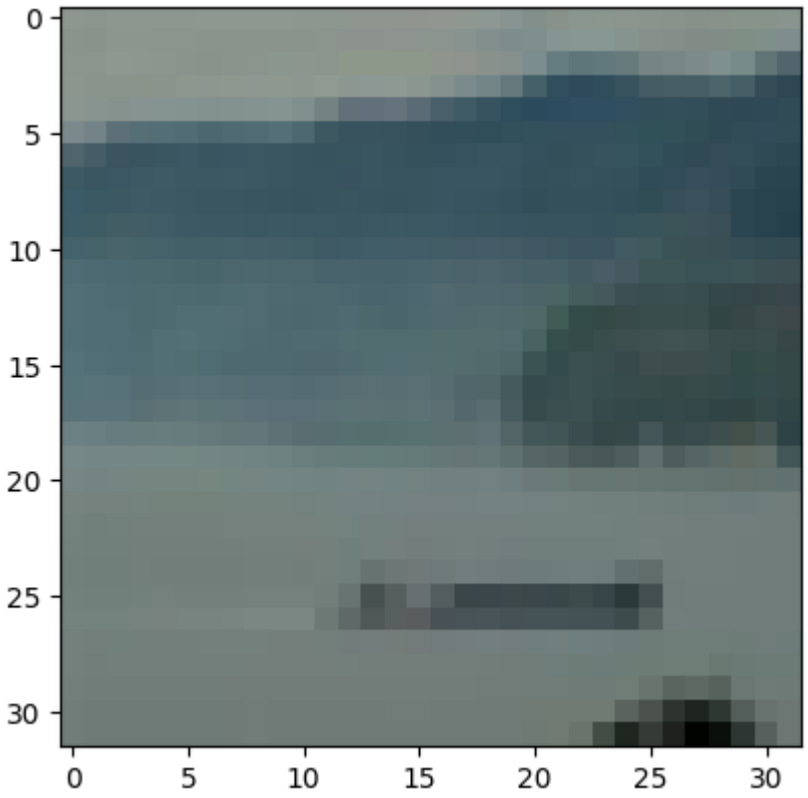
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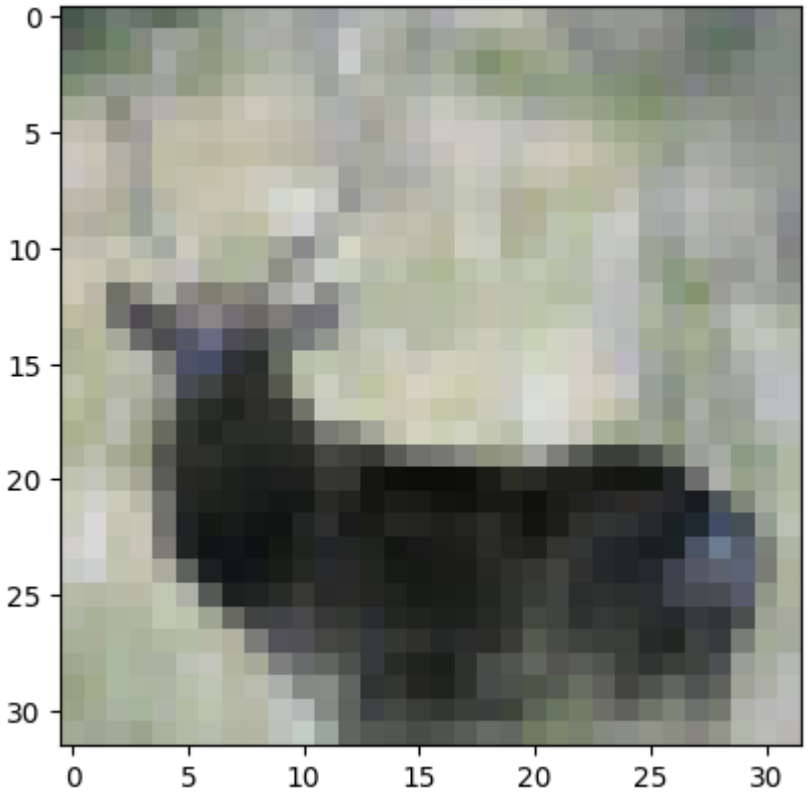


MODEL ARCHITECTURE

Build a Convolutional Neural Network (CNN) model.

Architecture:

Input -> Conv2D - BN-> Conv2D - BN-> MaxPooling2D -> Conv2D - BN-> Conv2D - BN-> MaxPooling2D -> Flatten -> Dense -> Dropout -> Dense -> Dropout -> Output

1. **Input Layer**
    - The input layer expects images of size 32x32 pixels with 3 color channels (RGB).
    - Data augmentation is applied to the input images.
    - The Rescaling layer, rescales the pixel values from the range [0, 255] to [0, 1].
2. **Convolutional Layers**
    - The model consists of 4 convolutional layers with 32, 64, 128, and 128 filters respectively.
3. **Max Pooling Layers**
    - Max pooling layers are used after each group of 2 convolutional layer to reduce the spatial dimensions of the feature maps.
    - A pooling size of 2x2 is used.
4. **Fully connected layer**
    - A dense layer with 512 units and ReLU activation function.

5. **Output Layer**

    - The output layer consists of 10 units (one for each class) with a softmax activation function.
    - The softmax function outputs the probability distribution over the classes.

Overfitting measures

- Dropout layers are used after each Convolutional and Dense layer to prevent overfitting.
- Kernel Regularization is used to prevent overfitting.

Batch Normalization

- Batch normalization is used after each Convolutional layer to normalize the activations of the previous layer at each batch.
- This helps to stabilize and speed up the training process.

Weight Initialization

- For the `ReLU` activation function, the `he_normal` initializer used to initialize the weights is considered a good weight initialization for ReLU activation functions.
- For the output layer using the `Softmax` activation function, the `glorot_uniform` initializer is used for the same reason.

In [ ]:
```
from tensorflow import keras
from keras import layers, regularizers

inputs = keras.Input(shape=(IMG_SIZE, IMG_SIZE, 3))

x = data_augmentation(inputs)

x = layers.Rescaling(1./255)(x)

## First Convolutional Block
x = layers.Conv2D(filters=32, kernel_size=3, kernel_initializer='he_norma
x = layers.BatchNormalization()(x) # Standardize the inputs to the next l
x = layers.Conv2D(filters=64, kernel_size=3, kernel_initializer='he_norma
x = layers.BatchNormalization()(x)

# First Block - Max Pooling and Dropout
x = layers.MaxPooling2D(pool_size=2)(x)
x = layers.Dropout(0.3)(x) # Drops 30% of the neurons randomly during tra

# Second Convolutional Block
x = layers.Conv2D(filters=128, kernel_size=3, kernel_initializer='he_norm
x = layers.BatchNormalization()(x)
x = layers.Conv2D(filters=128, kernel_size=3, kernel_initializer='he_norm
x = layers.BatchNormalization()(x)

# Second Block - Max Pooling and Dropout
x = layers.MaxPooling2D(pool_size=2)(x)
x = layers.Dropout(0.3)(x)

x = layers.Flatten()(x)
```

```
x = layers.Dense(512, kernel_initializer='he_normal', activation="relu")(
x = layers.Dropout(0.5)(x)

outputs = layers.Dense(10,  kernel_initializer='glorot_uniform', activati

model = keras.Model(inputs=inputs, outputs=outputs)
model.summary()
```

```
Model: "model"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 32, 32, 3)]       0

 sequential (Sequential)     (None, 32, 32, 3)         0

 rescaling (Rescaling)       (None, 32, 32, 3)         0

 conv2d (Conv2D)             (None, 30, 30, 32)        896

 batch_normalization (Batch  (None, 30, 30, 32)        128
 Normalization)

 conv2d_1 (Conv2D)           (None, 28, 28, 64)        18496

 batch_normalization_1 (Bat  (None, 28, 28, 64)        256
 chNormalization)

 max_pooling2d (MaxPooling2  (None, 14, 14, 64)        0
 D)

 dropout (Dropout)           (None, 14, 14, 64)        0

 conv2d_2 (Conv2D)           (None, 12, 12, 128)       73856

 batch_normalization_2 (Bat  (None, 12, 12, 128)       512
 chNormalization)

 conv2d_3 (Conv2D)           (None, 10, 10, 128)       147584

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_1 (InputLayer)        [(None, 32, 32, 3)]       0

 sequential (Sequential)     (None, 32, 32, 3)         0

 rescaling (Rescaling)       (None, 32, 32, 3)         0

 conv2d (Conv2D)             (None, 30, 30, 32)        896

 batch_normalization (Batch  (None, 30, 30, 32)        128
 Normalization)

 conv2d_1 (Conv2D)           (None, 28, 28, 64)        18496

 batch_normalization_1 (Bat  (None, 28, 28, 64)        256
 chNormalization)

 max_pooling2d (MaxPooling2  (None, 14, 14, 64)        0
 D)

 dropout (Dropout)           (None, 14, 14, 64)        0

 conv2d_2 (Conv2D)           (None, 12, 12, 128)       73856

 batch_normalization_2 (Bat  (None, 12, 12, 128)       512
 chNormalization)
```

```
conv2d_3 (Conv2D)           (None, 10, 10, 128)       147584

batch_normalization_3 (Bat  (None, 10, 10, 128)       512
chNormalization)

max_pooling2d_1 (MaxPoolin  (None, 5, 5, 128)         0
g2D)

dropout_1 (Dropout)         (None, 5, 5, 128)         0

flatten (Flatten)           (None, 3200)              0

dense (Dense)               (None, 512)               1638912

dropout_2 (Dropout)         (None, 512)               0

dense_1 (Dense)             (None, 10)                5130

=================================================================
Total params: 1886282 (7.20 MB)
Trainable params: 1885578 (7.19 MB)
Non-trainable params: 704 (2.75 KB)
_________________________________________________________________
```

Compile Model

Loss function:

We use the *Categorical Crossentropy* loss function because it is a `multi-class classification` problem.

Optimizer: Adam

We use the *Adam* optimizer because it is one of the best and most popular optimizers.

In [ ]:
```
model.compile(
    loss='categorical_crossentropy',
    optimizer='adam',
    metrics=['acc'])
```

Train Model

Train the model with Early stopping, Model checkpoint, and Learning rate reduction callbacks.

In [ ]:
```
from keras.callbacks import EarlyStopping, ModelCheckpoint, ReduceLROnPla

learning_rate_reduction = ReduceLROnPlateau(
    monitor='val_acc',
    patience=3,
    verbose=1,
    factor=0.5,
    min_lr=1e-5)

early_stop = EarlyStopping(monitor='val_acc',
                           patience=7,
```

```
                              restore_best_weights=True)
model_checkpoint = ModelCheckpoint('models/S01/checkpoints/S01-DA-cp.h5',

history = model.fit(
    train_dataset,
    epochs=100,
    validation_data=validation_dataset,
    callbacks=[early_stop, model_checkpoint, learning_rate_reduction])
```

```
Epoch 1/100
2024-06-22 20:44:33.120120: E tensorflow/core/grappler/optimizers/meta_opt
imizer.cc:961] layout failed: INVALID_ARGUMENT: Size of values 0 does not
match size of permutation 4 @ fanin shape inmodel/dropout/dropout/SelectV
2-2-TransposeNHWCToNCHW-LayoutOptimizer
2024-06-22 20:44:33.318379: I external/local_xla/xla/stream_executor/cuda/
cuda_dnn.cc:454] Loaded cuDNN version 8904
2024-06-22 20:44:34.433995: I external/local_xla/xla/service/service.cc:16
8] XLA service 0x7947f4ac3560 initialized for platform CUDA (this does not
guarantee that XLA will be used). Devices:
2024-06-22 20:44:34.434025: I external/local_xla/xla/service/service.cc:17
6]   StreamExecutor device (0): NVIDIA GeForce GTX 1060 6GB, Compute Capab
ility 6.1
2024-06-22 20:44:34.439490: I tensorflow/compiler/mlir/tensorflow/utils/du
mp_mlir_util.cc:269] disabling MLIR crash reproducer, set env var `MLIR_CR
ASH_REPRODUCER_DIRECTORY` to enable.
WARNING: All log messages before absl::InitializeLog() is called are writt
en to STDERR
I0000 00:00:1719085474.519916  120032 device_compiler.h:186] Compiled clus
ter using XLA!  This line is logged at most once for the lifetime of the p
rocess.
628/628 [==============================] - 18s 22ms/step - loss: 1.8973 -
acc: 0.3641 - val_loss: 1.9815 - val_acc: 0.4068 - lr: 0.0010
Epoch 2/100
  4/628 [..............................] - ETA: 13s - loss: 1.5817 - acc:
0.4805
/home/pws/miniconda3/envs/tensorflow/lib/python3.11/site-packages/keras/sr
c/engine/training.py:3103: UserWarning: You are saving your model as an HD
F5 file via `model.save()`. This file format is considered legacy. We reco
mmend using instead the native Keras format, e.g. `model.save('my_model.ke
ras')`.
  saving_api.save_model(
```

```
628/628 [==============================] - 13s 20ms/step - loss: 1.4920 -
acc: 0.4936 - val_loss: 1.3209 - val_acc: 0.5680 - lr: 0.0010
Epoch 3/100
628/628 [==============================] - 13s 21ms/step - loss: 1.3165 -
acc: 0.5602 - val_loss: 1.1575 - val_acc: 0.6255 - lr: 0.0010
Epoch 4/100
628/628 [==============================] - 13s 21ms/step - loss: 1.1937 -
acc: 0.6095 - val_loss: 1.0305 - val_acc: 0.6679 - lr: 0.0010
Epoch 5/100
628/628 [==============================] - 13s 21ms/step - loss: 1.1123 -
acc: 0.6425 - val_loss: 1.0317 - val_acc: 0.6793 - lr: 0.0010
Epoch 6/100
628/628 [==============================] - 13s 20ms/step - loss: 1.0571 -
acc: 0.6645 - val_loss: 0.9111 - val_acc: 0.7095 - lr: 0.0010
Epoch 7/100
628/628 [==============================] - 13s 20ms/step - loss: 1.0131 -
acc: 0.6822 - val_loss: 0.9219 - val_acc: 0.7183 - lr: 0.0010
Epoch 8/100
628/628 [==============================] - 13s 20ms/step - loss: 0.9734 -
acc: 0.7006 - val_loss: 0.8070 - val_acc: 0.7564 - lr: 0.0010
Epoch 9/100
628/628 [==============================] - 13s 21ms/step - loss: 0.9382 -
acc: 0.7161 - val_loss: 0.7755 - val_acc: 0.7641 - lr: 0.0010
Epoch 10/100
628/628 [==============================] - 13s 21ms/step - loss: 0.9213 -
acc: 0.7214 - val_loss: 0.8992 - val_acc: 0.7411 - lr: 0.0010
Epoch 11/100
628/628 [==============================] - 13s 21ms/step - loss: 0.8991 -
acc: 0.7330 - val_loss: 0.7490 - val_acc: 0.7832 - lr: 0.0010
Epoch 12/100
628/628 [==============================] - 13s 20ms/step - loss: 0.8784 -
acc: 0.7376 - val_loss: 0.7693 - val_acc: 0.7748 - lr: 0.0010
Epoch 13/100
628/628 [==============================] - 13s 21ms/step - loss: 0.8624 -
acc: 0.7461 - val_loss: 0.7865 - val_acc: 0.7711 - lr: 0.0010
Epoch 14/100
626/628 [==============================>.] - ETA: 0s - loss: 0.8417 - acc:
0.7558
Epoch 14: ReduceLROnPlateau reducing learning rate to 0.000500000023748725
7.
628/628 [==============================] - 13s 21ms/step - loss: 0.8416 -
acc: 0.7560 - val_loss: 0.8996 - val_acc: 0.7381 - lr: 0.0010
Epoch 15/100
628/628 [==============================] - 13s 21ms/step - loss: 0.7699 -
acc: 0.7773 - val_loss: 0.7265 - val_acc: 0.7888 - lr: 5.0000e-04
Epoch 16/100
628/628 [==============================] - 13s 21ms/step - loss: 0.7379 -
acc: 0.7888 - val_loss: 0.6861 - val_acc: 0.8112 - lr: 5.0000e-04
Epoch 17/100
628/628 [==============================] - 13s 21ms/step - loss: 0.7204 -
acc: 0.7926 - val_loss: 0.6775 - val_acc: 0.8102 - lr: 5.0000e-04
Epoch 18/100
628/628 [==============================] - 13s 20ms/step - loss: 0.7026 -
acc: 0.7981 - val_loss: 0.6817 - val_acc: 0.8063 - lr: 5.0000e-04
Epoch 19/100
628/628 [==============================] - 13s 21ms/step - loss: 0.6887 -
acc: 0.8020 - val_loss: 0.6258 - val_acc: 0.8214 - lr: 5.0000e-04
Epoch 20/100
628/628 [==============================] - 13s 21ms/step - loss: 0.6844 -
acc: 0.8029 - val_loss: 0.6144 - val_acc: 0.8290 - lr: 5.0000e-04
```

```
Epoch 21/100
628/628 [==============================] - 13s 21ms/step - loss: 0.6706 -
acc: 0.8067 - val_loss: 0.6152 - val_acc: 0.8281 - lr: 5.0000e-04
Epoch 22/100
628/628 [==============================] - 13s 21ms/step - loss: 0.6621 -
acc: 0.8098 - val_loss: 0.5726 - val_acc: 0.8431 - lr: 5.0000e-04
Epoch 23/100
628/628 [==============================] - 13s 20ms/step - loss: 0.6544 -
acc: 0.8130 - val_loss: 0.6520 - val_acc: 0.8167 - lr: 5.0000e-04
Epoch 24/100
628/628 [==============================] - 13s 20ms/step - loss: 0.6410 -
acc: 0.8162 - val_loss: 0.5887 - val_acc: 0.8355 - lr: 5.0000e-04
Epoch 25/100
627/628 [==============================>.] - ETA: 0s - loss: 0.6370 - acc:
0.8180
Epoch 25: ReduceLROnPlateau reducing learning rate to 0.000250000011874362
8.
628/628 [==============================] - 13s 21ms/step - loss: 0.6369 -
acc: 0.8180 - val_loss: 0.5882 - val_acc: 0.8371 - lr: 5.0000e-04
Epoch 26/100
628/628 [==============================] - 13s 21ms/step - loss: 0.5971 -
acc: 0.8313 - val_loss: 0.5663 - val_acc: 0.8429 - lr: 2.5000e-04
Epoch 27/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5829 -
acc: 0.8339 - val_loss: 0.5778 - val_acc: 0.8435 - lr: 2.5000e-04
Epoch 28/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5661 -
acc: 0.8408 - val_loss: 0.5358 - val_acc: 0.8544 - lr: 2.5000e-04
Epoch 29/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5622 -
acc: 0.8427 - val_loss: 0.5450 - val_acc: 0.8526 - lr: 2.5000e-04
Epoch 30/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5555 -
acc: 0.8437 - val_loss: 0.5246 - val_acc: 0.8578 - lr: 2.5000e-04
Epoch 31/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5489 -
acc: 0.8464 - val_loss: 0.5552 - val_acc: 0.8457 - lr: 2.5000e-04
Epoch 32/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5427 -
acc: 0.8483 - val_loss: 0.5598 - val_acc: 0.8423 - lr: 2.5000e-04
Epoch 33/100
626/628 [==============================>.] - ETA: 0s - loss: 0.5355 - acc:
0.8499
Epoch 33: ReduceLROnPlateau reducing learning rate to 0.000125000005937181
4.
628/628 [==============================] - 13s 21ms/step - loss: 0.5357 -
acc: 0.8499 - val_loss: 0.5237 - val_acc: 0.8559 - lr: 2.5000e-04
Epoch 34/100
628/628 [==============================] - 13s 21ms/step - loss: 0.5160 -
acc: 0.8563 - val_loss: 0.5276 - val_acc: 0.8570 - lr: 1.2500e-04
Epoch 35/100
628/628 [==============================] - 13s 20ms/step - loss: 0.5112 -
acc: 0.8562 - val_loss: 0.5252 - val_acc: 0.8607 - lr: 1.2500e-04
Epoch 36/100
628/628 [==============================] - 12s 18ms/step - loss: 0.5016 -
acc: 0.8611 - val_loss: 0.5083 - val_acc: 0.8611 - lr: 1.2500e-04
Epoch 37/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4921 -
acc: 0.8616 - val_loss: 0.5147 - val_acc: 0.8619 - lr: 1.2500e-04
Epoch 38/100
```

```
628/628 [==============================] - 11s 17ms/step - loss: 0.4934 -
acc: 0.8615 - val_loss: 0.5194 - val_acc: 0.8629 - lr: 1.2500e-04
Epoch 39/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4887 -
acc: 0.8630 - val_loss: 0.5109 - val_acc: 0.8621 - lr: 1.2500e-04
Epoch 40/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4858 -
acc: 0.8661 - val_loss: 0.5061 - val_acc: 0.8652 - lr: 1.2500e-04
Epoch 41/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4839 -
acc: 0.8629 - val_loss: 0.5397 - val_acc: 0.8539 - lr: 1.2500e-04
Epoch 42/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4867 -
acc: 0.8645 - val_loss: 0.5156 - val_acc: 0.8573 - lr: 1.2500e-04
Epoch 43/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4745 -
acc: 0.8677 - val_loss: 0.5036 - val_acc: 0.8659 - lr: 1.2500e-04
Epoch 44/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4700 -
acc: 0.8705 - val_loss: 0.5062 - val_acc: 0.8613 - lr: 1.2500e-04
Epoch 45/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4676 -
acc: 0.8687 - val_loss: 0.4858 - val_acc: 0.8707 - lr: 1.2500e-04
Epoch 46/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4676 -
acc: 0.8683 - val_loss: 0.4992 - val_acc: 0.8671 - lr: 1.2500e-04
Epoch 47/100
628/628 [==============================] - 11s 18ms/step - loss: 0.4648 -
acc: 0.8685 - val_loss: 0.4856 - val_acc: 0.8685 - lr: 1.2500e-04
Epoch 48/100
626/628 [============================>.] - ETA: 0s - loss: 0.4582 - acc:
0.8726
Epoch 48: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-0
5.
628/628 [==============================] - 11s 17ms/step - loss: 0.4582 -
acc: 0.8726 - val_loss: 0.5081 - val_acc: 0.8635 - lr: 1.2500e-04
Epoch 49/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4534 -
acc: 0.8744 - val_loss: 0.4932 - val_acc: 0.8663 - lr: 6.2500e-05
Epoch 50/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4506 -
acc: 0.8747 - val_loss: 0.4966 - val_acc: 0.8654 - lr: 6.2500e-05
Epoch 51/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4475 -
acc: 0.8747 - val_loss: 0.4784 - val_acc: 0.8722 - lr: 6.2500e-05
Epoch 52/100
628/628 [==============================] - 11s 18ms/step - loss: 0.4476 -
acc: 0.8760 - val_loss: 0.4831 - val_acc: 0.8691 - lr: 6.2500e-05
Epoch 53/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4484 -
acc: 0.8757 - val_loss: 0.4851 - val_acc: 0.8682 - lr: 6.2500e-05
Epoch 54/100
628/628 [==============================] - ETA: 0s - loss: 0.4421 - acc:
0.8771
Epoch 54: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-0
5.
628/628 [==============================] - 11s 17ms/step - loss: 0.4421 -
acc: 0.8771 - val_loss: 0.5002 - val_acc: 0.8647 - lr: 6.2500e-05
Epoch 55/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4303 -
```

```
acc: 0.8819 - val_loss: 0.4880 - val_acc: 0.8683 - lr: 3.1250e-05
Epoch 56/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4344 -
acc: 0.8798 - val_loss: 0.4743 - val_acc: 0.8745 - lr: 3.1250e-05
Epoch 57/100
628/628 [==============================] - 11s 17ms/step - loss: 0.4310 -
acc: 0.8813 - val_loss: 0.4825 - val_acc: 0.8707 - lr: 3.1250e-05
Epoch 58/100
628/628 [==============================] - 11s 18ms/step - loss: 0.4266 -
acc: 0.8827 - val_loss: 0.4868 - val_acc: 0.8692 - lr: 3.1250e-05
Epoch 59/100
626/628 [============================>.] - ETA: 0s - loss: 0.4321 - acc:
0.8809
Epoch 59: ReduceLROnPlateau reducing learning rate to 1.5625000742147677
e-05.
628/628 [==============================] - 12s 19ms/step - loss: 0.4320 -
acc: 0.8809 - val_loss: 0.4813 - val_acc: 0.8688 - lr: 3.1250e-05
Epoch 60/100
628/628 [==============================] - 11s 18ms/step - loss: 0.4277 -
acc: 0.8825 - val_loss: 0.4780 - val_acc: 0.8702 - lr: 1.5625e-05
Epoch 61/100
628/628 [==============================] - 11s 18ms/step - loss: 0.4259 -
acc: 0.8831 - val_loss: 0.4766 - val_acc: 0.8710 - lr: 1.5625e-05
Epoch 62/100
628/628 [==============================] - ETA: 0s - loss: 0.4266 - acc:
0.8831
Epoch 62: ReduceLROnPlateau reducing learning rate to 1e-05.
628/628 [==============================] - 12s 19ms/step - loss: 0.4266 -
acc: 0.8831 - val_loss: 0.4802 - val_acc: 0.8701 - lr: 1.5625e-05
Epoch 63/100
628/628 [==============================] - 11s 18ms/step - loss: 0.4231 -
acc: 0.8838 - val_loss: 0.4805 - val_acc: 0.8711 - lr: 1.0000e-05
```

Save Model

In [ ]:
```
keras.models.save_model(model, 'models/S01/S01-DA-model.h5')
```

```
/tmp/ipykernel_119953/3135399560.py:1: UserWarning: You are saving your mo
del as an HDF5 file via `model.save()`. This file format is considered leg
acy. We recommend using instead the native Keras format, e.g. `model.save
('my_model.keras')`.
  keras.models.save_model(model, 'models/S01/S01-DA-model.h5')
```

Load Model

In [ ]:
```
from tensorflow import keras
model = keras.models.load_model('models/S01/S01-DA-model.h5')
```

EVALUATION

Evaluate the model on the validation dataset.

In [ ]:
```
val_loss, val_acc = model.evaluate(validation_dataset)
print('val_acc:', val_acc)
```

```
157/157 [==============================] - 1s 5ms/step - loss: 0.4743 - ac
c: 0.8745
val_acc: 0.8744999766349792
```

Training and Validation Curves

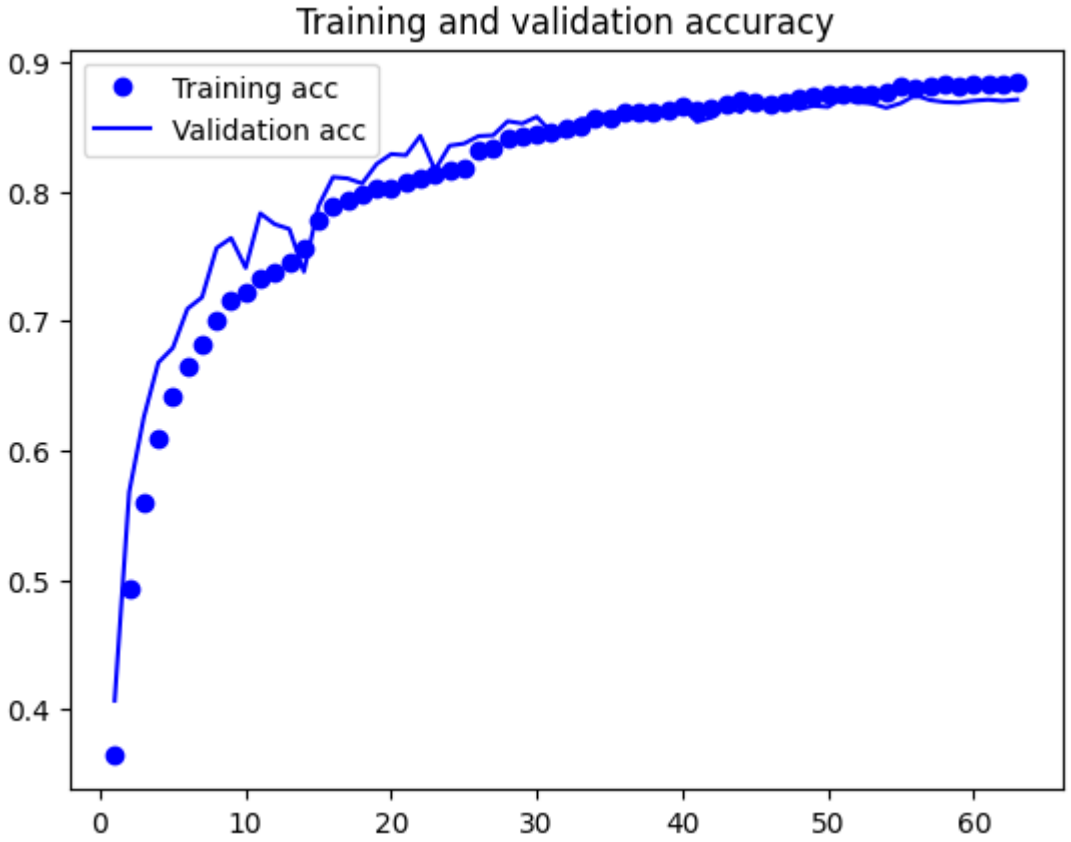
Plot the training and validation accuracy and loss curves.

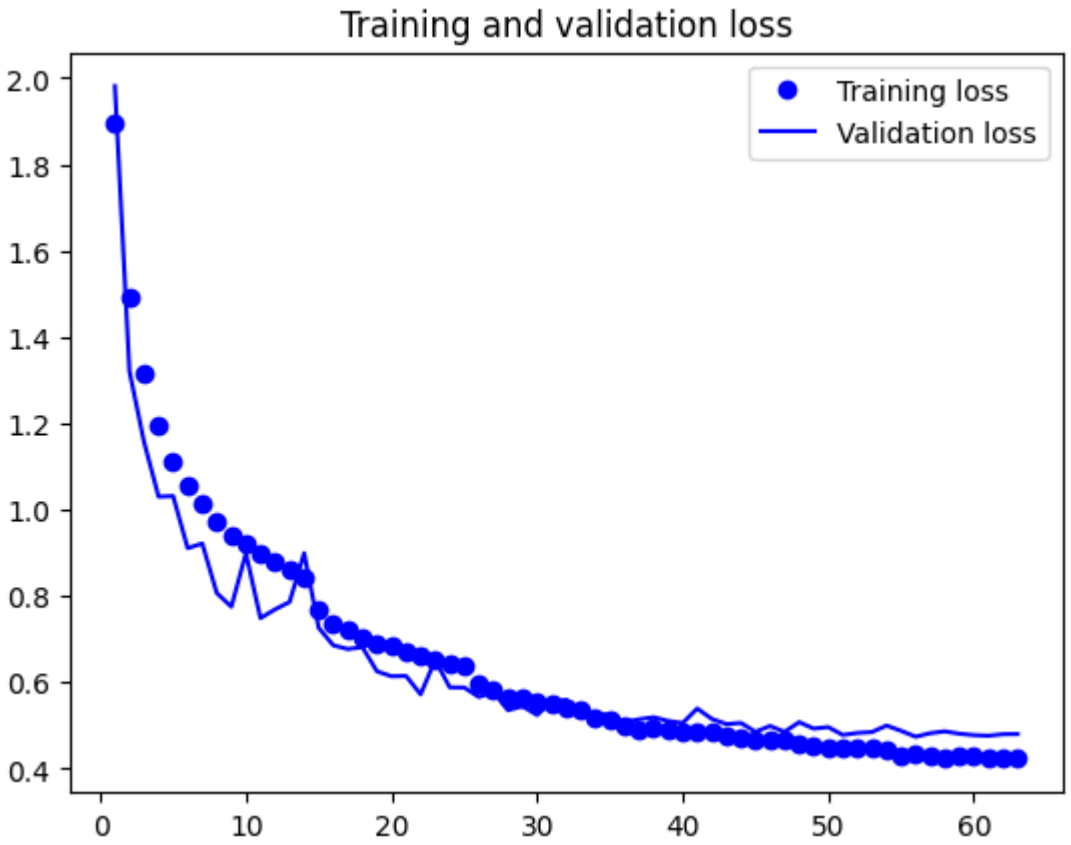
In [ ]:
```
import matplotlib.pyplot as plt

# Extract the history from the training process
acc = history.history['acc']
val_acc = history.history['val_acc']
loss = history.history['loss']
val_loss = history.history['val_loss']
epochs = range(1, len(acc) + 1)

# Plot the training and validation accuracy
plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Training and validation accuracy')
plt.legend()

# Plot the training and validation loss
plt.figure()
plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()
plt.show()
```





Confusion Matrix

In [ ]:
```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.metrics import confusion_matrix
```

```
y_true = []
y_pred = []

for features, labels in validation_dataset:
    predictions = model.predict(features)
    y_true.extend(np.argmax(labels.numpy(), axis=1))
    y_pred.extend(np.argmax(predictions, axis=1))

y_true = np.array(y_true)
y_pred = np.array(y_pred)

cm = confusion_matrix(y_true, y_pred)

# Plot the confusion matrix
plt.figure(figsize=(10, 8))
sns.heatmap(cm, annot=True, cmap='Blues', fmt='g')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.title('Confusion Matrix')
plt.show()
```

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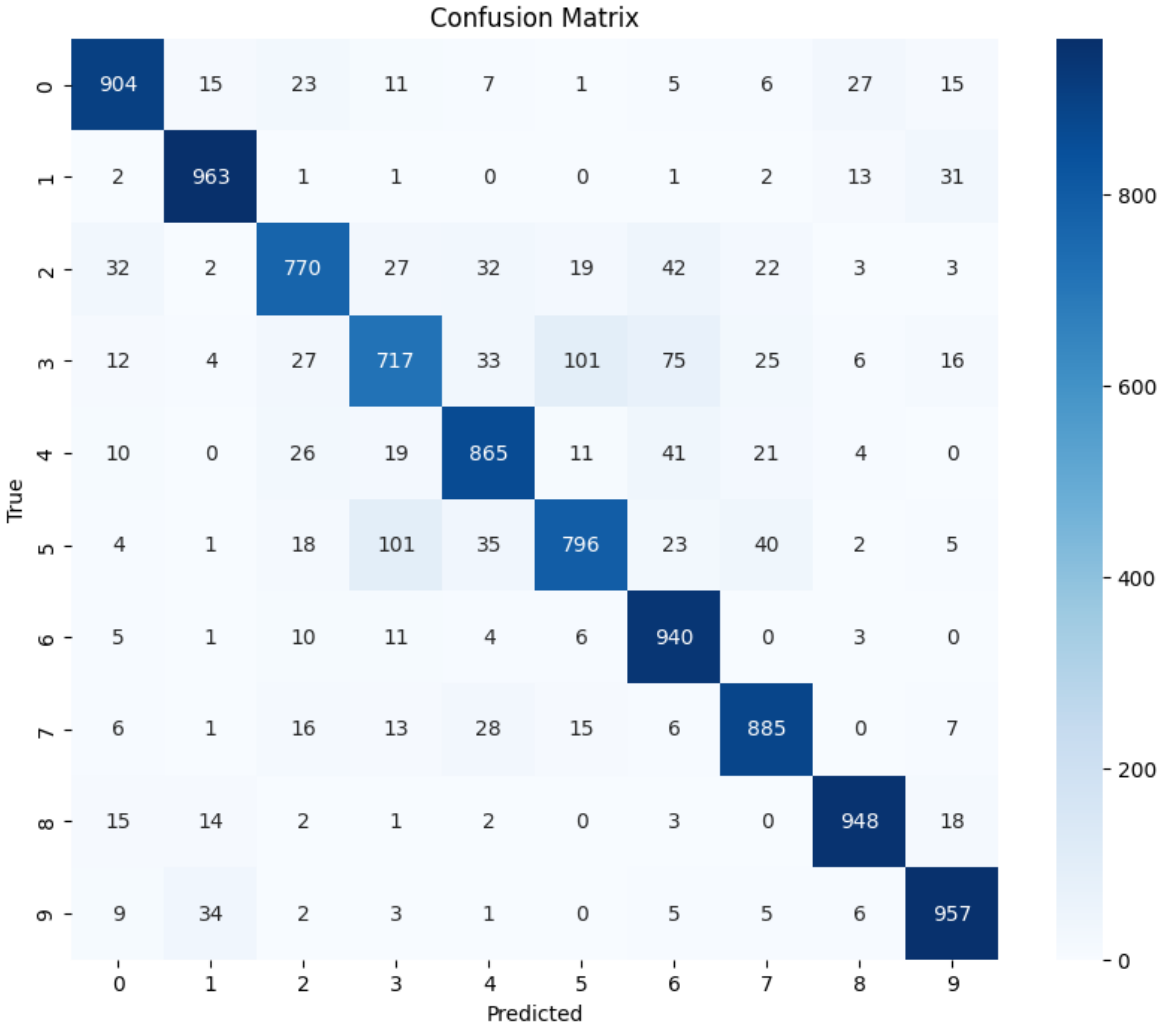
```



In [ ]:
```
print("Confusion Matrix:")
print(cm)
```

```
Confusion Matrix:
[[904  15  23  11   7   1   5   6  27  15]
 [  2 963   1   1   0   0   1   2  13  31]
 [ 32   2 770  27  32  19  42  22   3   3]
 [ 12   4  27 717  33 101  75  25   6  16]
 [ 10   0  26  19 865  11  41  21   4   0]
 [  4   1  18 101  35 796  23  40   2   5]
 [  5   1  10  11   4   6 940   0   3   0]
 [  6   1  16  13  28  15   6 885   0   7]
 [ 15  14   2   1   2   0   3   0 948  18]
 [  9  34   2   3   1   0   5   5   6 957]]
```

In [ ]:
```
from sklearn.metrics import classification_report

report = classification_report(y_true, y_pred, target_names=class_names)
print(report)
```

	precision	recall	f1-score	support
airplane	0.90	0.89	0.90	1014
automobile	0.93	0.95	0.94	1014
bird	0.86	0.81	0.83	952
cat	0.79	0.71	0.75	1016
deer	0.86	0.87	0.86	997
dog	0.84	0.78	0.81	1025
frog	0.82	0.96	0.89	980
horse	0.88	0.91	0.89	977
ship	0.94	0.95	0.94	1003
truck	0.91	0.94	0.92	1022
accuracy			0.87	10000
macro avg	0.87	0.87	0.87	10000
weighted avg	0.87	0.87	0.87	10000

Predictions

Predict and visualize the results for a sample image.

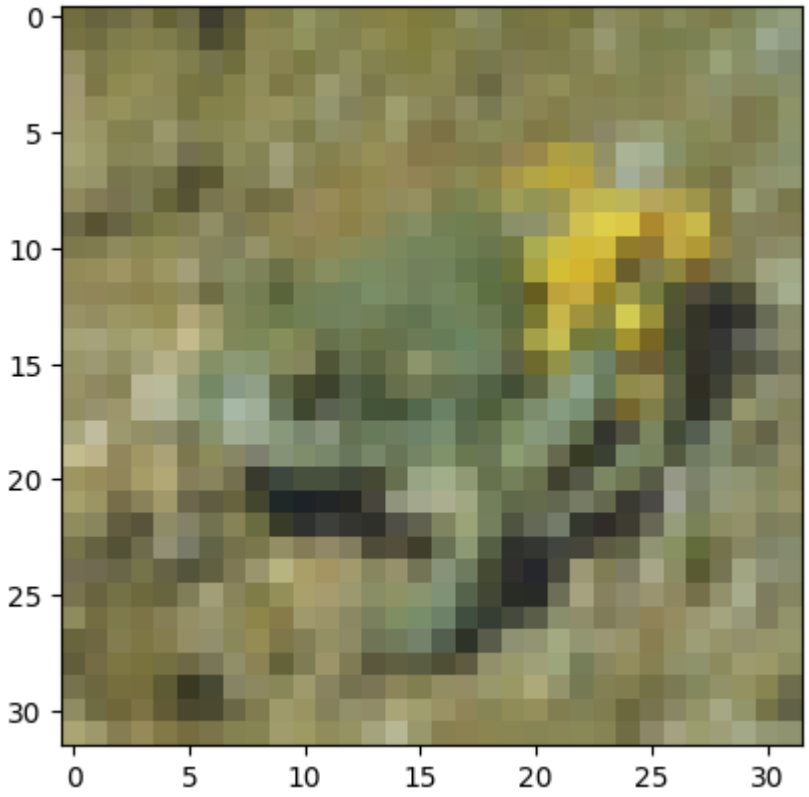
In [ ]:
```
import tensorflow as tf
import matplotlib.pyplot as plt
from keras.preprocessing import image

# Load an image
img = tf.keras.preprocessing.image.load_img(train_dirs[0] + '/006_frog/al
# img = tf.keras.preprocessing.image.load_img(train_dirs[0] + '/000_airpl

img_array = image.img_to_array(img)
img_array = tf.expand_dims(img_array, 0)

plt.imshow(img)
plt.show()

print(img_array.shape)
result = model.predict(img_array)
print("Result: ", result.round())
```




```
(1, 32, 32, 3)
1/1 [==============================] - 0s 229ms/step
Result:  [[0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]]
```