Music Genre Classification with GTZAN Dataset

Audio Files | Mel Spectrograms | CSV with extracted features

In this Project we learn basic information about audio data, which are needed for using audio in Machine Learning and Deep Learning models.

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Import Libraries

In [3]:

```
# imoprt libraries
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline

from glob import glob # allows us to list all files to a directory
import IPython
import IPython.display as ipd # to play the Audio Files

import librosa # main package for working with Audio Data
import librosa.display
```

In [4]:

```
# Make a list of all the wav files in the dataset and store them in a variable
audio_files = glob("/kaggle/input/gtzan-dataset-music-genre-classification/Data/genres_o
```

In [5]:

```
# Play the first Audio file
ipd.Audio(audio_files[0])
```

Out[5]:

0:00 / 0:30

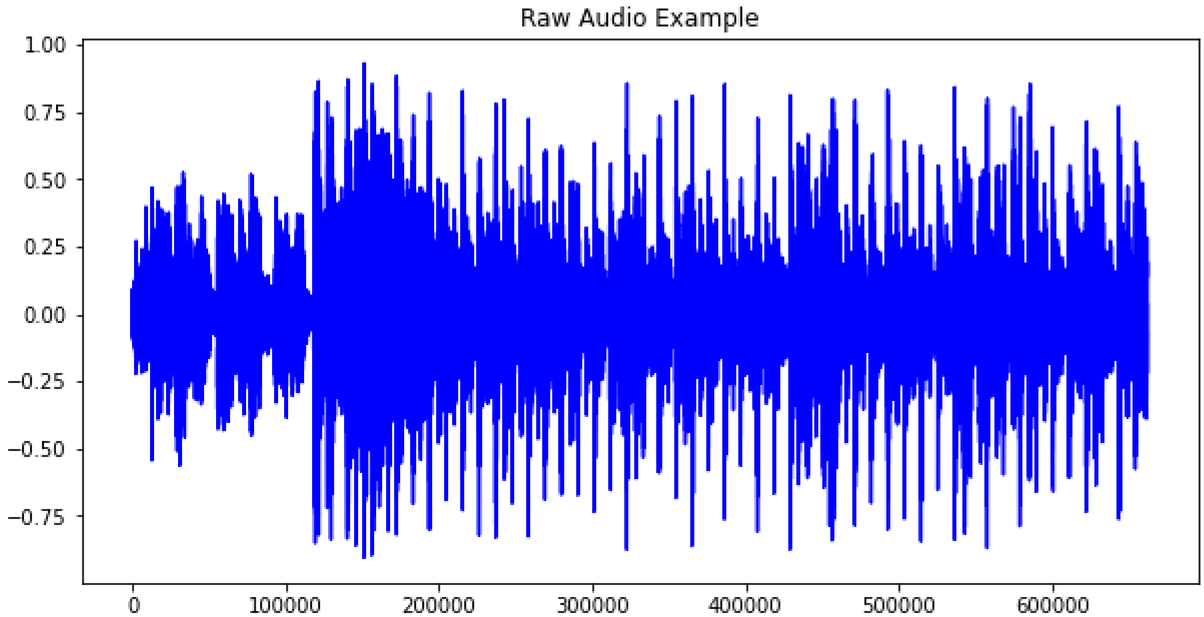
In [6]:

```
# load the audio file and show raw data and sample rate
y, sr = librosa.load(audio_files[0])
print("Y is a numpy array:", y)
print("Shape of Y:", y.shape)
print("Sample Rate:", sr)
```

```
Y is a numpy array: [-0.0196228  -0.00567627  0.00927734 ...  0.01547241  0.01220703
  0.0319519 ]
Shape of Y: (661794,)
Sample Rate: 22050
```

In [7]:

```
# turn raw data array to pd series and plot the audio example
pd.Series(y).plot(figsize=(10,5), title="Raw Audio Example", color='blue');
```

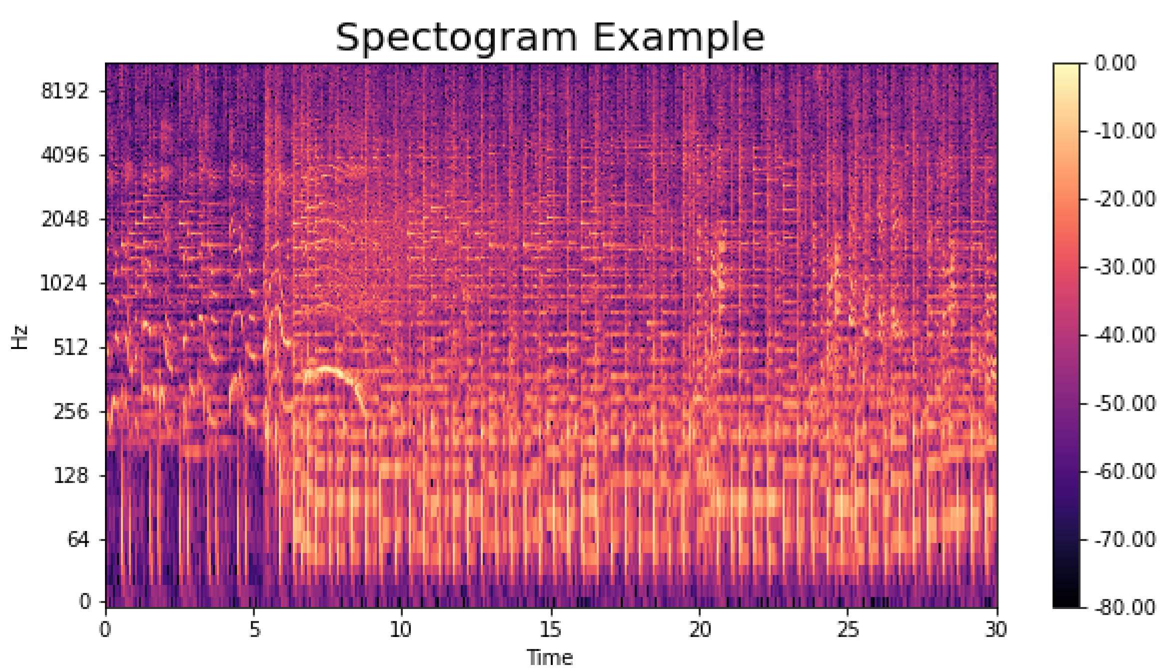


In [8]:
```
# Use STFT on raw audio data
D = librosa.stft(y)
# convert from aplitude to decibel values by taking the absolute value of D in reference
S_db = librosa.amplitude_to_db(np.abs(D), ref=np.max)
# see the shape of transformed data
print("New shape of transformed data", S_db.shape)
```

```
New shape of transformed data (1025, 1293)
```

Plotting Audio File as a Spectogram

In [9]:
```
# plot transformed data as spectogram
fig, ax = plt.subplots(figsize=(10,5))
img = librosa.display.specshow(S_db, x_axis='time', y_axis='log', ax=ax)
ax.set_title('Spectogram Example', fontsize=20)
fig.colorbar(img, ax=ax, format=f'%0.2f');
```



In [10]:
```
# apply mel spectogram without STFT
S = librosa.feature.melspectrogram(y, sr=sr, n_mels=128*2)
print("Shape of Mel Spectogram", S.shape)
```

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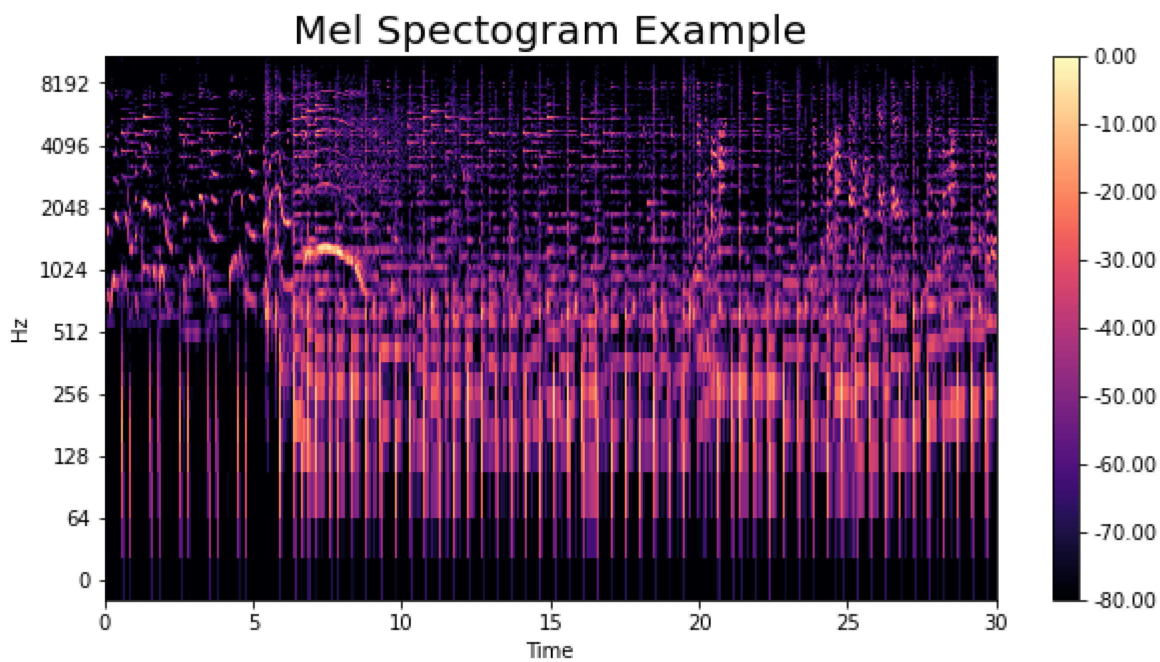
```
# use that converting function as above
S_db_mel = librosa.amplitude_to_db(S, ref=np.max)
```

```
Shape of Mel Spectogram (256, 1293)
```

```
/opt/conda/lib/python3.7/site-packages/ipykernel_launcher.py:2: FutureWarning: Pass y=[-
0.0196228  -0.00567627  0.00927734 ...  0.01547241  0.01220703
  0.0319519 ] as keyword args. From version 0.10 passing these as positional arguments w
ill result in an error
```

In [11]:
```
# plot the mel spectogram
fig, ax = plt.subplots(figsize=(10,5))
img = librosa.display.specshow(S_db_mel, x_axis='time', y_axis='log', ax=ax)
ax.set_title('Mel Spectogram Example', fontsize=20)
fig.colorbar(img, ax=ax, format=f'%0.2f');
```



EDA - Exploratory Data Analysis

In [12]:
```
# load csv file
df = pd.read_csv("/kaggle/input/gtzan-dataset-music-genre-classification/Data/features_3
```

In [13]:
```
df.head() # first 5 entries
```

Out[13]:

	filename	length	chroma_stft_mean	chroma_stft_var	rms_mean	rms_var	spectral_centroid_mean
0	blues.00000.0.wav	66149	0.335406	0.091048	0.130405	0.003521	1773.065032
1	blues.00000.1.wav	66149	0.343065	0.086147	0.112699	0.001450	1816.693777
2	blues.00000.2.wav	66149	0.346815	0.092243	0.132003	0.004620	1788.539719
3	blues.00000.3.wav	66149	0.363639	0.086856	0.132565	0.002448	1655.289045
4	blues.00000.4.wav	66149	0.335579	0.088129	0.143289	0.001701	1630.656199

5 rows × 60 columns

In [14]:
```
df.shape # see the shape of df
```

Out[14]:
```
(9990, 60)
```

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In [15]:

```
df.info() # infos about the samples, features and datatypes
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 9990 entries, 0 to 9989
Data columns (total 60 columns):
 #   Column                   Non-Null Count  Dtype  
---  ------                   --------------  -----  
 0   filename                 9990 non-null   object 
 1   length                   9990 non-null   int64  
 2   chroma_stft_mean         9990 non-null   float64
 3   chroma_stft_var          9990 non-null   float64
 4   rms_mean                 9990 non-null   float64
 5   rms_var                  9990 non-null   float64
 6   spectral_centroid_mean   9990 non-null   float64
 7   spectral_centroid_var    9990 non-null   float64
 8   spectral_bandwidth_mean  9990 non-null   float64
 9   spectral_bandwidth_var   9990 non-null   float64
 10  rolloff_mean             9990 non-null   float64
 11  rolloff_var              9990 non-null   float64
 12  zero_crossing_rate_mean  9990 non-null   float64
 13  zero_crossing_rate_var   9990 non-null   float64
 14  harmony_mean             9990 non-null   float64
 15  harmony_var              9990 non-null   float64
 16  perceptr_mean            9990 non-null   float64
 17  perceptr_var             9990 non-null   float64
 18  tempo                    9990 non-null   float64
 19  mfcc1_mean               9990 non-null   float64
 20  mfcc1_var                9990 non-null   float64
 21  mfcc2_mean               9990 non-null   float64
 22  mfcc2_var                9990 non-null   float64
 23  mfcc3_mean               9990 non-null   float64
 24  mfcc3_var                9990 non-null   float64
 25  mfcc4_mean               9990 non-null   float64
 26  mfcc4_var                9990 non-null   float64
 27  mfcc5_mean               9990 non-null   float64
 28  mfcc5_var                9990 non-null   float64
 29  mfcc6_mean               9990 non-null   float64
 30  mfcc6_var                9990 non-null   float64
 31  mfcc7_mean               9990 non-null   float64
 32  mfcc7_var                9990 non-null   float64
 33  mfcc8_mean               9990 non-null   float64
 34  mfcc8_var                9990 non-null   float64
 35  mfcc9_mean               9990 non-null   float64
 36  mfcc9_var                9990 non-null   float64
 37  mfcc10_mean              9990 non-null   float64
 38  mfcc10_var               9990 non-null   float64
 39  mfcc11_mean              9990 non-null   float64
 40  mfcc11_var               9990 non-null   float64
 41  mfcc12_mean              9990 non-null   float64
 42  mfcc12_var               9990 non-null   float64
 43  mfcc13_mean              9990 non-null   float64
 44  mfcc13_var               9990 non-null   float64
 45  mfcc14_mean              9990 non-null   float64
 46  mfcc14_var               9990 non-null   float64
 47  mfcc15_mean              9990 non-null   float64
 48  mfcc15_var               9990 non-null   float64
 49  mfcc16_mean              9990 non-null   float64
 50  mfcc16_var               9990 non-null   float64
 51  mfcc17_mean              9990 non-null   float64
 52  mfcc17_var               9990 non-null   float64
 53  mfcc18_mean              9990 non-null   float64
 54  mfcc18_var               9990 non-null   float64
 55  mfcc19_mean              9990 non-null   float64
 56  mfcc19_var               9990 non-null   float64
 57  mfcc20_mean              9990 non-null   float64
 58  mfcc20_var               9990 non-null   float64
```

```
 59  label                    9990 non-null   object
dtypes: float64(57), int64(1), object(2)
memory usage: 4.6+ MB
```

In [16]:
```
df.isnull().sum() # checking for missing values
```

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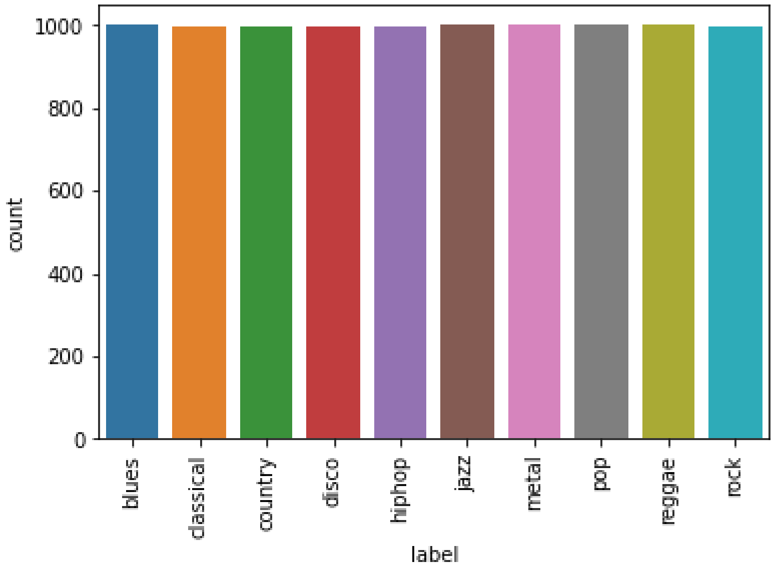
Out[16]:
```
filename                   0
length                     0
chroma_stft_mean           0
chroma_stft_var            0
rms_mean                   0
rms_var                    0
spectral_centroid_mean     0
spectral_centroid_var      0
spectral_bandwidth_mean    0
spectral_bandwidth_var     0
rolloff_mean               0
rolloff_var                0
zero_crossing_rate_mean    0
zero_crossing_rate_var     0
harmony_mean               0
harmony_var                0
perceptr_mean              0
perceptr_var               0
tempo                      0
mfcc1_mean                 0
mfcc1_var                  0
mfcc2_mean                 0
mfcc2_var                  0
mfcc3_mean                 0
mfcc3_var                  0
mfcc4_mean                 0
mfcc4_var                  0
mfcc5_mean                 0
mfcc5_var                  0
mfcc6_mean                 0
mfcc6_var                  0
mfcc7_mean                 0
mfcc7_var                  0
mfcc8_mean                 0
mfcc8_var                  0
mfcc9_mean                 0
mfcc9_var                  0
mfcc10_mean                0
mfcc10_var                 0
mfcc11_mean                0
mfcc11_var                 0
mfcc12_mean                0
mfcc12_var                 0
mfcc13_mean                0
mfcc13_var                 0
mfcc14_mean                0
mfcc14_var                 0
mfcc15_mean                0
mfcc15_var                 0
mfcc16_mean                0
mfcc16_var                 0
mfcc17_mean                0
mfcc17_var                 0
mfcc18_mean                0
mfcc18_var                 0
mfcc19_mean                0
mfcc19_var                 0
mfcc20_mean                0
mfcc20_var                 0
label                      0
dtype: int64
```

In [17]:
```
sns.countplot(x=df.label) # plot the categories
plt.xticks(rotation=90);
```



Data Preproccesing

In [18]:
```
# drop filename column and show new df first 5 entries
df = df.drop(labels='filename',axis=1)
df.head()
```

Out[18]:

	length	chroma_stft_mean	chroma_stft_var	rms_mean	rms_var	spectral_centroid_mean	spectral_centroid_v
0	66149	0.335406	0.091048	0.130405	0.003521	1773.065032	167541.6308
1	66149	0.343065	0.086147	0.112699	0.001450	1816.693777	90525.6908
2	66149	0.346815	0.092243	0.132003	0.004620	1788.539719	111407.4376
3	66149	0.363639	0.086856	0.132565	0.002448	1655.289045	111952.2845
4	66149	0.335579	0.088129	0.143289	0.001701	1630.656199	79667.2676

5 rows × 59 columns

In [20]:
```
# import labelencoder and scaler
from sklearn.preprocessing import LabelEncoder
from sklearn.preprocessing import StandardScaler
encoder = LabelEncoder()
scaler = StandardScaler()
```

In [21]:
```
data = df.iloc[:, :-1] # get the other columns
data
```

Out[21]:

	length	chroma_stft_mean	chroma_stft_var	rms_mean	rms_var	spectral_centroid_mean	spectral_centro
0	66149	0.335406	0.091048	0.130405	0.003521	1773.065032	167541.6
1	66149	0.343065	0.086147	0.112699	0.001450	1816.693777	90525.6
2	66149	0.346815	0.092243	0.132003	0.004620	1788.539719	111407.4
3	66149	0.363639	0.086856	0.132565	0.002448	1655.289045	111952.2
4	66149	0.335579	0.088129	0.143289	0.001701	1630.656199	79667.2
...	...	...	...	...	...	...	
9985	66149	0.349126	0.080515	0.050019	0.000097	1499.083005	164266.8
9986	66149	0.372564	0.082626	0.057897	0.000088	1847.965128	281054.9
9987	66149	0.347481	0.089019	0.052403	0.000701	1346.157659	662956.2
9988	66149	0.387527	0.084815	0.066430	0.000320	2084.515327	203891.0
9989	66149	0.369293	0.086759	0.050524	0.000067	1634.330126	411429.1

9990 rows × 58 columns

In [22]:
```
labels = df.iloc[:, -1] # get labels column
labels.to_frame()
```

Out[22]:

	label
0	blues
1	blues
2	blues
3	blues
4	blues
...	...
9985	rock
9986	rock
9987	rock
9988	rock
9989	rock

9990 rows × 1 columns

Getting x and y ready

In [23]:
```
# assign x and y, scale x and encode y
x = np.array(data, dtype = float)
x = scaler.fit_transform(data)
y = encoder.fit_transform(labels)
x.shape, y.shape
```

Out[23]:
```
((9990, 58), (9990,))
```

In [24]:
```
# split data to train and test data
from sklearn.model_selection import train_test_split
```

```
x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.33)
x_train.shape, x_test.shape, y_train.shape, y_test.shape
```

Out[24]:

```
((6693, 58), (3297, 58), (6693,), (3297,))
```

Modelling using CNN

In [26]:

```
# import deep learning libraries
import tensorflow as tf
from tensorflow import keras
from keras.models import Sequential
```

In [27]:

```
# build model
model = keras.models.Sequential([
    keras.layers.Dense(512, activation="relu", input_shape=(x_train.shape[1],)),
    keras.layers.Dropout(0.2),
    keras.layers.Dense(256,activation="relu"),
    keras.layers.Dropout(0.2),
    keras.layers.Dense(128,activation="relu"),
    keras.layers.Dropout(0.2),
    keras.layers.Dense(64,activation="relu"),
    keras.layers.Dropout(0.2),
    keras.layers.Dense(10, activation="softmax"),

])
```

```
2023-01-31 03:10:22.818886: I tensorflow/core/common_runtime/process_util.cc:146] Creati
ng new thread pool with default inter op setting: 2. Tune using inter_op_parallelism_thr
eads for best performance.
```

In [28]:

```
print(model.summary()) # show summary of model
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense (Dense)                (None, 512)               30208
_________________________________________________________________
dropout (Dropout)            (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 256)               131328
_________________________________________________________________
dropout_1 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_2 (Dense)              (None, 128)               32896
_________________________________________________________________
dropout_2 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_3 (Dense)              (None, 64)                8256
_________________________________________________________________
dropout_3 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_4 (Dense)              (None, 10)                650
=================================================================
Total params: 203,338
Trainable params: 203,338
Non-trainable params: 0
_________________________________________________________________
None
```

In [29]:

```
# compile model
model.compile(optimizer='adam', loss='sparse_categorical_crossentropy',metrics='accuracy'
```

In [30]:
```
# fit model - training
history = model.fit(x_train, y_train, validation_data=(x_test, y_test), epochs=300, batc
```

```
2023-01-31 03:12:53.715391: I tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:1
85] None of the MLIR Optimization Passes are enabled (registered 2)
```

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```
Epoch 1/300
53/53 [==============================] - 2s 14ms/step - loss: 1.6888 - accuracy: 0.4001
- val_loss: 1.1452 - val_accuracy: 0.5936
Epoch 2/300
53/53 [==============================] - 1s 10ms/step - loss: 1.1211 - accuracy: 0.6153
- val_loss: 0.8906 - val_accuracy: 0.6991
Epoch 3/300
53/53 [==============================] - 0s 9ms/step - loss: 0.9269 - accuracy: 0.6798 -
val_loss: 0.7619 - val_accuracy: 0.7413
Epoch 4/300
53/53 [==============================] - 0s 9ms/step - loss: 0.7953 - accuracy: 0.7338 -
val_loss: 0.7118 - val_accuracy: 0.7631
Epoch 5/300
53/53 [==============================] - 0s 9ms/step - loss: 0.6987 - accuracy: 0.7660 -
val_loss: 0.6379 - val_accuracy: 0.7880
Epoch 6/300
53/53 [==============================] - 0s 9ms/step - loss: 0.6220 - accuracy: 0.7962 -
val_loss: 0.5899 - val_accuracy: 0.8077
Epoch 7/300
53/53 [==============================] - 1s 10ms/step - loss: 0.5623 - accuracy: 0.8128
- val_loss: 0.5615 - val_accuracy: 0.8156
Epoch 8/300
53/53 [==============================] - 0s 9ms/step - loss: 0.4986 - accuracy: 0.8325 -
val_loss: 0.5401 - val_accuracy: 0.8262
Epoch 9/300
53/53 [==============================] - 0s 9ms/step - loss: 0.4703 - accuracy: 0.8446 -
val_loss: 0.5000 - val_accuracy: 0.8329
Epoch 10/300
53/53 [==============================] - 0s 9ms/step - loss: 0.4237 - accuracy: 0.8594 -
val_loss: 0.4826 - val_accuracy: 0.8474
Epoch 11/300
53/53 [==============================] - 1s 10ms/step - loss: 0.3802 - accuracy: 0.8787
- val_loss: 0.4419 - val_accuracy: 0.8568
Epoch 12/300
53/53 [==============================] - 1s 10ms/step - loss: 0.3550 - accuracy: 0.8859
- val_loss: 0.4543 - val_accuracy: 0.8584
Epoch 13/300
53/53 [==============================] - 1s 10ms/step - loss: 0.3157 - accuracy: 0.8980
- val_loss: 0.4290 - val_accuracy: 0.8702
Epoch 14/300
53/53 [==============================] - 1s 11ms/step - loss: 0.2914 - accuracy: 0.9050
- val_loss: 0.4403 - val_accuracy: 0.8653
Epoch 15/300
53/53 [==============================] - 1s 11ms/step - loss: 0.2648 - accuracy: 0.9160
- val_loss: 0.4412 - val_accuracy: 0.8693
Epoch 16/300
53/53 [==============================] - 1s 11ms/step - loss: 0.2476 - accuracy: 0.9190
- val_loss: 0.4184 - val_accuracy: 0.8747
Epoch 17/300
53/53 [==============================] - 1s 10ms/step - loss: 0.2346 - accuracy: 0.9210
- val_loss: 0.3948 - val_accuracy: 0.8844
Epoch 18/300
53/53 [==============================] - 1s 10ms/step - loss: 0.2230 - accuracy: 0.9223
- val_loss: 0.3905 - val_accuracy: 0.8829
Epoch 19/300
53/53 [==============================] - 1s 10ms/step - loss: 0.2130 - accuracy: 0.9302
- val_loss: 0.3941 - val_accuracy: 0.8850
Epoch 20/300
53/53 [==============================] - 1s 12ms/step - loss: 0.2048 - accuracy: 0.9320
- val_loss: 0.4027 - val_accuracy: 0.8844
Epoch 21/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1918 - accuracy: 0.9389
- val_loss: 0.3826 - val_accuracy: 0.8878
Epoch 22/300
```

```
53/53 [==============================] - 1s 10ms/step - loss: 0.1539 - accuracy: 0.9504
- val_loss: 0.3872 - val_accuracy: 0.8890
Epoch 23/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1701 - accuracy: 0.9428
- val_loss: 0.3648 - val_accuracy: 0.8966
Epoch 24/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1410 - accuracy: 0.9556
- val_loss: 0.3745 - val_accuracy: 0.8966
Epoch 25/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1421 - accuracy: 0.9526
- val_loss: 0.4155 - val_accuracy: 0.8829
Epoch 26/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1302 - accuracy: 0.9582
- val_loss: 0.3728 - val_accuracy: 0.8972
Epoch 27/300
53/53 [==============================] - 0s 9ms/step - loss: 0.1393 - accuracy: 0.9535 -
val_loss: 0.3655 - val_accuracy: 0.8972
Epoch 28/300
53/53 [==============================] - 1s 9ms/step - loss: 0.1259 - accuracy: 0.9550 -
val_loss: 0.3920 - val_accuracy: 0.8944
Epoch 29/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1080 - accuracy: 0.9668
- val_loss: 0.3866 - val_accuracy: 0.9026
Epoch 30/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1017 - accuracy: 0.9643
- val_loss: 0.3969 - val_accuracy: 0.8996
Epoch 31/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1032 - accuracy: 0.9677
- val_loss: 0.4086 - val_accuracy: 0.8969
Epoch 32/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1068 - accuracy: 0.9670
- val_loss: 0.3967 - val_accuracy: 0.8957
Epoch 33/300
53/53 [==============================] - 1s 10ms/step - loss: 0.1059 - accuracy: 0.9674
- val_loss: 0.3933 - val_accuracy: 0.8984
Epoch 34/300
53/53 [==============================] - 1s 15ms/step - loss: 0.1002 - accuracy: 0.9679
- val_loss: 0.4340 - val_accuracy: 0.8902
Epoch 35/300
53/53 [==============================] - 1s 17ms/step - loss: 0.0871 - accuracy: 0.9740
- val_loss: 0.4161 - val_accuracy: 0.8972
Epoch 36/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0924 - accuracy: 0.9701
- val_loss: 0.4168 - val_accuracy: 0.9014
Epoch 37/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0888 - accuracy: 0.9743
- val_loss: 0.4103 - val_accuracy: 0.9005
Epoch 38/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0779 - accuracy: 0.9749
- val_loss: 0.4347 - val_accuracy: 0.8987
Epoch 39/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0839 - accuracy: 0.9707
- val_loss: 0.4174 - val_accuracy: 0.9032
Epoch 40/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0839 - accuracy: 0.9707
- val_loss: 0.4161 - val_accuracy: 0.9014
Epoch 41/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0826 - accuracy: 0.9733
- val_loss: 0.3964 - val_accuracy: 0.9039
Epoch 42/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0835 - accuracy: 0.9728
- val_loss: 0.3821 - val_accuracy: 0.9090
Epoch 43/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0670 - accuracy: 0.9798 -
```

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val_loss: 0.4286 - val_accuracy: 0.9045
Epoch 44/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0772 - accuracy: 0.9740
- val_loss: 0.4190 - val_accuracy: 0.9020
Epoch 45/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0706 - accuracy: 0.9780
- val_loss: 0.4284 - val_accuracy: 0.9014
Epoch 46/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0674 - accuracy: 0.9797
- val_loss: 0.4105 - val_accuracy: 0.9045
Epoch 47/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0638 - accuracy: 0.9803
- val_loss: 0.4048 - val_accuracy: 0.9035
Epoch 48/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0572 - accuracy: 0.9804
- val_loss: 0.4160 - val_accuracy: 0.9063
Epoch 49/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0626 - accuracy: 0.9785
- val_loss: 0.4226 - val_accuracy: 0.9035
Epoch 50/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0658 - accuracy: 0.9786
- val_loss: 0.3937 - val_accuracy: 0.9054
Epoch 51/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0583 - accuracy: 0.9824
- val_loss: 0.4041 - val_accuracy: 0.9039
Epoch 52/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0636 - accuracy: 0.9791
- val_loss: 0.4148 - val_accuracy: 0.9075
Epoch 53/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0504 - accuracy: 0.9831
- val_loss: 0.4331 - val_accuracy: 0.9069
Epoch 54/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0538 - accuracy: 0.9846
- val_loss: 0.4235 - val_accuracy: 0.9054
Epoch 55/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0598 - accuracy: 0.9803
- val_loss: 0.4032 - val_accuracy: 0.9075
Epoch 56/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0546 - accuracy: 0.9819
- val_loss: 0.4030 - val_accuracy: 0.9099
Epoch 57/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0418 - accuracy: 0.9885
- val_loss: 0.4250 - val_accuracy: 0.9032
Epoch 58/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0487 - accuracy: 0.9854
- val_loss: 0.4056 - val_accuracy: 0.9142
Epoch 59/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0423 - accuracy: 0.9854
- val_loss: 0.4259 - val_accuracy: 0.9093
Epoch 60/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0537 - accuracy: 0.9831
- val_loss: 0.4439 - val_accuracy: 0.9069
Epoch 61/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0587 - accuracy: 0.9837
- val_loss: 0.4246 - val_accuracy: 0.9087
Epoch 62/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0559 - accuracy: 0.9834
- val_loss: 0.4188 - val_accuracy: 0.9093
Epoch 63/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0615 - accuracy: 0.9825
- val_loss: 0.4142 - val_accuracy: 0.9011
Epoch 64/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0664 - accuracy: 0.9800
- val_loss: 0.4083 - val_accuracy: 0.9090
```

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Epoch 65/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0465 - accuracy: 0.9860
- val_loss: 0.4539 - val_accuracy: 0.9096
Epoch 66/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0559 - accuracy: 0.9828
- val_loss: 0.4243 - val_accuracy: 0.9099
Epoch 67/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0541 - accuracy: 0.9846
- val_loss: 0.3933 - val_accuracy: 0.9178
Epoch 68/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0511 - accuracy: 0.9834
- val_loss: 0.3997 - val_accuracy: 0.9142
Epoch 69/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0369 - accuracy: 0.9886
- val_loss: 0.4446 - val_accuracy: 0.9090
Epoch 70/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0393 - accuracy: 0.9867
- val_loss: 0.4338 - val_accuracy: 0.9111
Epoch 71/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0498 - accuracy: 0.9842
- val_loss: 0.4352 - val_accuracy: 0.9093
Epoch 72/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0581 - accuracy: 0.9833
- val_loss: 0.4290 - val_accuracy: 0.9093
Epoch 73/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0450 - accuracy: 0.9860
- val_loss: 0.4406 - val_accuracy: 0.9042
Epoch 74/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0494 - accuracy: 0.9830
- val_loss: 0.4392 - val_accuracy: 0.9066
Epoch 75/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0486 - accuracy: 0.9858
- val_loss: 0.4003 - val_accuracy: 0.9120
Epoch 76/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0470 - accuracy: 0.9846
- val_loss: 0.4145 - val_accuracy: 0.9069
Epoch 77/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0388 - accuracy: 0.9888
- val_loss: 0.4104 - val_accuracy: 0.9123
Epoch 78/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0352 - accuracy: 0.9886
- val_loss: 0.4131 - val_accuracy: 0.9139
Epoch 79/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0301 - accuracy: 0.9906
- val_loss: 0.4685 - val_accuracy: 0.9090
Epoch 80/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0417 - accuracy: 0.9876
- val_loss: 0.4381 - val_accuracy: 0.9099
Epoch 81/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0513 - accuracy: 0.9858
- val_loss: 0.4081 - val_accuracy: 0.9145
Epoch 82/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0402 - accuracy: 0.9895
- val_loss: 0.4475 - val_accuracy: 0.9133
Epoch 83/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0479 - accuracy: 0.9870
- val_loss: 0.4636 - val_accuracy: 0.9105
Epoch 84/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0664 - accuracy: 0.9816
- val_loss: 0.4248 - val_accuracy: 0.9078
Epoch 85/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0461 - accuracy: 0.9869
- val_loss: 0.4510 - val_accuracy: 0.9054
Epoch 86/300
```

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53/53 [==============================] - 1s 10ms/step - loss: 0.0459 - accuracy: 0.9842
- val_loss: 0.4595 - val_accuracy: 0.9051
Epoch 87/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0416 - accuracy: 0.9876
- val_loss: 0.4338 - val_accuracy: 0.9075
Epoch 88/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0349 - accuracy: 0.9903
- val_loss: 0.4375 - val_accuracy: 0.9126
Epoch 89/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0333 - accuracy: 0.9886
- val_loss: 0.4510 - val_accuracy: 0.9123
Epoch 90/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0390 - accuracy: 0.9891 -
val_loss: 0.4391 - val_accuracy: 0.9136
Epoch 91/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0356 - accuracy: 0.9888
- val_loss: 0.4478 - val_accuracy: 0.9102
Epoch 92/300
53/53 [==============================] - 1s 22ms/step - loss: 0.0382 - accuracy: 0.9888
- val_loss: 0.4939 - val_accuracy: 0.9105
Epoch 93/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0437 - accuracy: 0.9879
- val_loss: 0.4523 - val_accuracy: 0.9084
Epoch 94/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0316 - accuracy: 0.9906
- val_loss: 0.4328 - val_accuracy: 0.9123
Epoch 95/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0262 - accuracy: 0.9918
- val_loss: 0.4547 - val_accuracy: 0.9163
Epoch 96/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0404 - accuracy: 0.9872
- val_loss: 0.4291 - val_accuracy: 0.9148
Epoch 97/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0275 - accuracy: 0.9912
- val_loss: 0.4206 - val_accuracy: 0.9178
Epoch 98/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0352 - accuracy: 0.9891
- val_loss: 0.4578 - val_accuracy: 0.9066
Epoch 99/300
53/53 [==============================] - 1s 13ms/step - loss: 0.0377 - accuracy: 0.9869
- val_loss: 0.4244 - val_accuracy: 0.9120
Epoch 100/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0350 - accuracy: 0.9910
- val_loss: 0.4567 - val_accuracy: 0.9126
Epoch 101/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0335 - accuracy: 0.9880
- val_loss: 0.4544 - val_accuracy: 0.9133
Epoch 102/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0422 - accuracy: 0.9864
- val_loss: 0.4163 - val_accuracy: 0.9154
Epoch 103/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0303 - accuracy: 0.9912
- val_loss: 0.4488 - val_accuracy: 0.9123
Epoch 104/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0280 - accuracy: 0.9927 -
val_loss: 0.4591 - val_accuracy: 0.9133
Epoch 105/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0314 - accuracy: 0.9904
- val_loss: 0.4706 - val_accuracy: 0.9111
Epoch 106/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0273 - accuracy: 0.9918
- val_loss: 0.4545 - val_accuracy: 0.9178
Epoch 107/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0224 - accuracy: 0.9933 -
```

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val_loss: 0.4368 - val_accuracy: 0.9178
Epoch 108/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0343 - accuracy: 0.9907
- val_loss: 0.4555 - val_accuracy: 0.9148
Epoch 109/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0348 - accuracy: 0.9895
- val_loss: 0.4564 - val_accuracy: 0.9187
Epoch 110/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0370 - accuracy: 0.9883
- val_loss: 0.4371 - val_accuracy: 0.9166
Epoch 111/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0316 - accuracy: 0.9892
- val_loss: 0.4495 - val_accuracy: 0.9130
Epoch 112/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0446 - accuracy: 0.9874
- val_loss: 0.4710 - val_accuracy: 0.9142
Epoch 113/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0345 - accuracy: 0.9897 -
val_loss: 0.4552 - val_accuracy: 0.9133
Epoch 114/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0298 - accuracy: 0.9901
- val_loss: 0.4196 - val_accuracy: 0.9126
Epoch 115/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0242 - accuracy: 0.9921
- val_loss: 0.4829 - val_accuracy: 0.9126
Epoch 116/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0291 - accuracy: 0.9912 -
val_loss: 0.4795 - val_accuracy: 0.9120
Epoch 117/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0292 - accuracy: 0.9904 -
val_loss: 0.4832 - val_accuracy: 0.9145
Epoch 118/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0404 - accuracy: 0.9879 -
val_loss: 0.4547 - val_accuracy: 0.9084
Epoch 119/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0225 - accuracy: 0.9931
- val_loss: 0.4951 - val_accuracy: 0.9084
Epoch 120/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0255 - accuracy: 0.9925
- val_loss: 0.4540 - val_accuracy: 0.9151
Epoch 121/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0206 - accuracy: 0.9928
- val_loss: 0.4392 - val_accuracy: 0.9166
Epoch 122/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0271 - accuracy: 0.9916
- val_loss: 0.4691 - val_accuracy: 0.9126
Epoch 123/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0276 - accuracy: 0.9903
- val_loss: 0.4816 - val_accuracy: 0.9081
Epoch 124/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0321 - accuracy: 0.9898 -
val_loss: 0.4356 - val_accuracy: 0.9130
Epoch 125/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0422 - accuracy: 0.9873
- val_loss: 0.4497 - val_accuracy: 0.9130
Epoch 126/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0322 - accuracy: 0.9903
- val_loss: 0.4807 - val_accuracy: 0.9139
Epoch 127/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0315 - accuracy: 0.9913
- val_loss: 0.4556 - val_accuracy: 0.9148
Epoch 128/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0277 - accuracy: 0.9912
- val_loss: 0.4487 - val_accuracy: 0.9163
```

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Epoch 129/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0248 - accuracy: 0.9940
- val_loss: 0.4410 - val_accuracy: 0.9184
Epoch 130/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0244 - accuracy: 0.9919 -
val_loss: 0.4665 - val_accuracy: 0.9136
Epoch 131/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0276 - accuracy: 0.9919
- val_loss: 0.4478 - val_accuracy: 0.9166
Epoch 132/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0240 - accuracy: 0.9927
- val_loss: 0.4296 - val_accuracy: 0.9151
Epoch 133/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0266 - accuracy: 0.9921
- val_loss: 0.4386 - val_accuracy: 0.9148
Epoch 134/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0215 - accuracy: 0.9931
- val_loss: 0.4626 - val_accuracy: 0.9154
Epoch 135/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0269 - accuracy: 0.9925
- val_loss: 0.4956 - val_accuracy: 0.9108
Epoch 136/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0308 - accuracy: 0.9901
- val_loss: 0.4743 - val_accuracy: 0.9111
Epoch 137/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0337 - accuracy: 0.9882
- val_loss: 0.4737 - val_accuracy: 0.9123
Epoch 138/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0243 - accuracy: 0.9925
- val_loss: 0.4763 - val_accuracy: 0.9160
Epoch 139/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0243 - accuracy: 0.9937
- val_loss: 0.4643 - val_accuracy: 0.9142
Epoch 140/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0314 - accuracy: 0.9907
- val_loss: 0.4717 - val_accuracy: 0.9142
Epoch 141/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0262 - accuracy: 0.9924
- val_loss: 0.4520 - val_accuracy: 0.9175
Epoch 142/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0254 - accuracy: 0.9925 -
val_loss: 0.4511 - val_accuracy: 0.9160
Epoch 143/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0178 - accuracy: 0.9954 -
val_loss: 0.4693 - val_accuracy: 0.9178
Epoch 144/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0226 - accuracy: 0.9924 -
val_loss: 0.4773 - val_accuracy: 0.9120
Epoch 145/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0295 - accuracy: 0.9903 -
val_loss: 0.5029 - val_accuracy: 0.9142
Epoch 146/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0267 - accuracy: 0.9916
- val_loss: 0.4370 - val_accuracy: 0.9181
Epoch 147/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0239 - accuracy: 0.9936
- val_loss: 0.4316 - val_accuracy: 0.9190
Epoch 148/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0283 - accuracy: 0.9930
- val_loss: 0.4752 - val_accuracy: 0.9102
Epoch 149/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0247 - accuracy: 0.9925
- val_loss: 0.4866 - val_accuracy: 0.9181
Epoch 150/300
```

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53/53 [==============================] - 1s 13ms/step - loss: 0.0242 - accuracy: 0.9927
- val_loss: 0.4792 - val_accuracy: 0.9193
Epoch 151/300
53/53 [==============================] - 1s 19ms/step - loss: 0.0190 - accuracy: 0.9943
- val_loss: 0.4737 - val_accuracy: 0.9154
Epoch 152/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0223 - accuracy: 0.9924 -
val_loss: 0.4919 - val_accuracy: 0.9151
Epoch 153/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0202 - accuracy: 0.9936
- val_loss: 0.5237 - val_accuracy: 0.9133
Epoch 154/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0411 - accuracy: 0.9891 -
val_loss: 0.4692 - val_accuracy: 0.9145
Epoch 155/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0207 - accuracy: 0.9933 -
val_loss: 0.4724 - val_accuracy: 0.9120
Epoch 156/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0196 - accuracy: 0.9942 -
val_loss: 0.4744 - val_accuracy: 0.9221
Epoch 157/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0220 - accuracy: 0.9937
- val_loss: 0.4763 - val_accuracy: 0.9202
Epoch 158/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0217 - accuracy: 0.9922 -
val_loss: 0.4658 - val_accuracy: 0.9148
Epoch 159/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0392 - accuracy: 0.9891
- val_loss: 0.4711 - val_accuracy: 0.9105
Epoch 160/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0272 - accuracy: 0.9924
- val_loss: 0.4949 - val_accuracy: 0.9154
Epoch 161/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0225 - accuracy: 0.9924
- val_loss: 0.4939 - val_accuracy: 0.9105
Epoch 162/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0287 - accuracy: 0.9931
- val_loss: 0.4935 - val_accuracy: 0.9154
Epoch 163/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0175 - accuracy: 0.9952
- val_loss: 0.4747 - val_accuracy: 0.9190
Epoch 164/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0316 - accuracy: 0.9907
- val_loss: 0.5223 - val_accuracy: 0.9081
Epoch 165/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0255 - accuracy: 0.9918
- val_loss: 0.4798 - val_accuracy: 0.9154
Epoch 166/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0205 - accuracy: 0.9927
- val_loss: 0.4878 - val_accuracy: 0.9142
Epoch 167/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0111 - accuracy: 0.9960 -
val_loss: 0.5138 - val_accuracy: 0.9126
Epoch 168/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0138 - accuracy: 0.9954 -
val_loss: 0.5229 - val_accuracy: 0.9120
Epoch 169/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0258 - accuracy: 0.9927
- val_loss: 0.4875 - val_accuracy: 0.9166
Epoch 170/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0255 - accuracy: 0.9927
- val_loss: 0.4625 - val_accuracy: 0.9178
Epoch 171/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0207 - accuracy: 0.9934
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- val_loss: 0.4601 - val_accuracy: 0.9205
Epoch 172/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0229 - accuracy: 0.9924
- val_loss: 0.4763 - val_accuracy: 0.9145
Epoch 173/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0143 - accuracy: 0.9960
- val_loss: 0.4849 - val_accuracy: 0.9157
Epoch 174/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0144 - accuracy: 0.9966
- val_loss: 0.5338 - val_accuracy: 0.9175
Epoch 175/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0212 - accuracy: 0.9933 -
val_loss: 0.4956 - val_accuracy: 0.9184
Epoch 176/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0174 - accuracy: 0.9939
- val_loss: 0.5129 - val_accuracy: 0.9154
Epoch 177/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0141 - accuracy: 0.9943
- val_loss: 0.5188 - val_accuracy: 0.9163
Epoch 178/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0146 - accuracy: 0.9942
- val_loss: 0.5752 - val_accuracy: 0.9136
Epoch 179/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0233 - accuracy: 0.9943
- val_loss: 0.5342 - val_accuracy: 0.9184
Epoch 180/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0219 - accuracy: 0.9946
- val_loss: 0.5903 - val_accuracy: 0.9126
Epoch 181/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0225 - accuracy: 0.9922
- val_loss: 0.6376 - val_accuracy: 0.9069
Epoch 182/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0334 - accuracy: 0.9907
- val_loss: 0.6046 - val_accuracy: 0.9087
Epoch 183/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0317 - accuracy: 0.9912
- val_loss: 0.5091 - val_accuracy: 0.9111
Epoch 184/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0252 - accuracy: 0.9906
- val_loss: 0.5427 - val_accuracy: 0.9087
Epoch 185/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0242 - accuracy: 0.9927
- val_loss: 0.5423 - val_accuracy: 0.9096
Epoch 186/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0244 - accuracy: 0.9928
- val_loss: 0.4941 - val_accuracy: 0.9151
Epoch 187/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0226 - accuracy: 0.9928
- val_loss: 0.5218 - val_accuracy: 0.9130
Epoch 188/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0252 - accuracy: 0.9924
- val_loss: 0.5391 - val_accuracy: 0.9084
Epoch 189/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0214 - accuracy: 0.9942
- val_loss: 0.4868 - val_accuracy: 0.9190
Epoch 190/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0182 - accuracy: 0.9940
- val_loss: 0.4987 - val_accuracy: 0.9190
Epoch 191/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0176 - accuracy: 0.9946
- val_loss: 0.4861 - val_accuracy: 0.9175
Epoch 192/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0147 - accuracy: 0.9957
- val_loss: 0.4815 - val_accuracy: 0.9224
```

```
Epoch 193/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0120 - accuracy: 0.9961
- val_loss: 0.4798 - val_accuracy: 0.9242
Epoch 194/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0222 - accuracy: 0.9949
- val_loss: 0.5569 - val_accuracy: 0.9130
Epoch 195/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0203 - accuracy: 0.9925
- val_loss: 0.4919 - val_accuracy: 0.9166
Epoch 196/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0231 - accuracy: 0.9928
- val_loss: 0.4625 - val_accuracy: 0.9199
Epoch 197/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0180 - accuracy: 0.9952
- val_loss: 0.4842 - val_accuracy: 0.9199
Epoch 198/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0146 - accuracy: 0.9957
- val_loss: 0.4925 - val_accuracy: 0.9187
Epoch 199/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0221 - accuracy: 0.9945
- val_loss: 0.4695 - val_accuracy: 0.9199
Epoch 200/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0275 - accuracy: 0.9921
- val_loss: 0.5453 - val_accuracy: 0.9120
Epoch 201/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0213 - accuracy: 0.9933
- val_loss: 0.4736 - val_accuracy: 0.9184
Epoch 202/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0171 - accuracy: 0.9948
- val_loss: 0.5300 - val_accuracy: 0.9151
Epoch 203/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0201 - accuracy: 0.9952
- val_loss: 0.5292 - val_accuracy: 0.9181
Epoch 204/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0177 - accuracy: 0.9949
- val_loss: 0.4898 - val_accuracy: 0.9166
Epoch 205/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0218 - accuracy: 0.9943
- val_loss: 0.5086 - val_accuracy: 0.9114
Epoch 206/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0186 - accuracy: 0.9948
- val_loss: 0.5632 - val_accuracy: 0.9087
Epoch 207/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0222 - accuracy: 0.9931
- val_loss: 0.5517 - val_accuracy: 0.9075
Epoch 208/300
53/53 [==============================] - 1s 26ms/step - loss: 0.0172 - accuracy: 0.9939
- val_loss: 0.4850 - val_accuracy: 0.9181
Epoch 209/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0168 - accuracy: 0.9943
- val_loss: 0.5003 - val_accuracy: 0.9175
Epoch 210/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0132 - accuracy: 0.9954
- val_loss: 0.5173 - val_accuracy: 0.9199
Epoch 211/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0108 - accuracy: 0.9958
- val_loss: 0.5476 - val_accuracy: 0.9139
Epoch 212/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0238 - accuracy: 0.9937
- val_loss: 0.5697 - val_accuracy: 0.9120
Epoch 213/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0233 - accuracy: 0.9925
- val_loss: 0.5444 - val_accuracy: 0.9096
Epoch 214/300
```

```
53/53 [==============================] - 1s 10ms/step - loss: 0.0202 - accuracy: 0.9931
- val_loss: 0.5621 - val_accuracy: 0.9114
Epoch 215/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0169 - accuracy: 0.9948
- val_loss: 0.5416 - val_accuracy: 0.9120
Epoch 216/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0138 - accuracy: 0.9958
- val_loss: 0.5414 - val_accuracy: 0.9169
Epoch 217/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0285 - accuracy: 0.9925 -
val_loss: 0.5109 - val_accuracy: 0.9166
Epoch 218/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0209 - accuracy: 0.9939
- val_loss: 0.5386 - val_accuracy: 0.9120
Epoch 219/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0262 - accuracy: 0.9933
- val_loss: 0.4591 - val_accuracy: 0.9190
Epoch 220/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0160 - accuracy: 0.9957
- val_loss: 0.5132 - val_accuracy: 0.9178
Epoch 221/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0222 - accuracy: 0.9937
- val_loss: 0.5377 - val_accuracy: 0.9181
Epoch 222/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0141 - accuracy: 0.9949
- val_loss: 0.5775 - val_accuracy: 0.9202
Epoch 223/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0195 - accuracy: 0.9930
- val_loss: 0.5079 - val_accuracy: 0.9169
Epoch 224/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0224 - accuracy: 0.9934
- val_loss: 0.5244 - val_accuracy: 0.9166
Epoch 225/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0185 - accuracy: 0.9934
- val_loss: 0.4812 - val_accuracy: 0.9208
Epoch 226/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0159 - accuracy: 0.9949
- val_loss: 0.5477 - val_accuracy: 0.9136
Epoch 227/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0183 - accuracy: 0.9958
- val_loss: 0.4890 - val_accuracy: 0.9196
Epoch 228/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0132 - accuracy: 0.9949
- val_loss: 0.4899 - val_accuracy: 0.9227
Epoch 229/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0197 - accuracy: 0.9946
- val_loss: 0.4936 - val_accuracy: 0.9196
Epoch 230/300
53/53 [==============================] - 1s 14ms/step - loss: 0.0151 - accuracy: 0.9954
- val_loss: 0.5391 - val_accuracy: 0.9175
Epoch 231/300
53/53 [==============================] - 1s 14ms/step - loss: 0.0129 - accuracy: 0.9964
- val_loss: 0.4980 - val_accuracy: 0.9187
Epoch 232/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0198 - accuracy: 0.9948
- val_loss: 0.4917 - val_accuracy: 0.9217
Epoch 233/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0102 - accuracy: 0.9963
- val_loss: 0.5386 - val_accuracy: 0.9178
Epoch 234/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0166 - accuracy: 0.9946
- val_loss: 0.5928 - val_accuracy: 0.9148
Epoch 235/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0255 - accuracy: 0.9910
```

```
- val_loss: 0.5288 - val_accuracy: 0.9136
Epoch 236/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0219 - accuracy: 0.9936
- val_loss: 0.5163 - val_accuracy: 0.9175
Epoch 237/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0247 - accuracy: 0.9924
- val_loss: 0.5052 - val_accuracy: 0.9190
Epoch 238/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0198 - accuracy: 0.9928
- val_loss: 0.5157 - val_accuracy: 0.9172
Epoch 239/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0174 - accuracy: 0.9937
- val_loss: 0.4995 - val_accuracy: 0.9178
Epoch 240/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0353 - accuracy: 0.9892
- val_loss: 0.4890 - val_accuracy: 0.9193
Epoch 241/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0163 - accuracy: 0.9945
- val_loss: 0.5080 - val_accuracy: 0.9214
Epoch 242/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0136 - accuracy: 0.9957
- val_loss: 0.4694 - val_accuracy: 0.9281
Epoch 243/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0137 - accuracy: 0.9951
- val_loss: 0.5065 - val_accuracy: 0.9221
Epoch 244/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0165 - accuracy: 0.9955
- val_loss: 0.5159 - val_accuracy: 0.9221
Epoch 245/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0130 - accuracy: 0.9963
- val_loss: 0.5528 - val_accuracy: 0.9208
Epoch 246/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0164 - accuracy: 0.9960
- val_loss: 0.5107 - val_accuracy: 0.9184
Epoch 247/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0162 - accuracy: 0.9957
- val_loss: 0.5133 - val_accuracy: 0.9202
Epoch 248/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0175 - accuracy: 0.9946
- val_loss: 0.4911 - val_accuracy: 0.9224
Epoch 249/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0203 - accuracy: 0.9943
- val_loss: 0.5075 - val_accuracy: 0.9239
Epoch 250/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0114 - accuracy: 0.9958
- val_loss: 0.5568 - val_accuracy: 0.9211
Epoch 251/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0132 - accuracy: 0.9957
- val_loss: 0.5629 - val_accuracy: 0.9202
Epoch 252/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0126 - accuracy: 0.9964
- val_loss: 0.5568 - val_accuracy: 0.9211
Epoch 253/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0187 - accuracy: 0.9948
- val_loss: 0.5554 - val_accuracy: 0.9178
Epoch 254/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0159 - accuracy: 0.9942
- val_loss: 0.5396 - val_accuracy: 0.9233
Epoch 255/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0177 - accuracy: 0.9946
- val_loss: 0.5257 - val_accuracy: 0.9227
Epoch 256/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0176 - accuracy: 0.9943
- val_loss: 0.5110 - val_accuracy: 0.9260
```

```
Epoch 257/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0162 - accuracy: 0.9943
- val_loss: 0.5562 - val_accuracy: 0.9224
Epoch 258/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0254 - accuracy: 0.9930 -
val_loss: 0.4884 - val_accuracy: 0.9196
Epoch 259/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0142 - accuracy: 0.9951
- val_loss: 0.5115 - val_accuracy: 0.9251
Epoch 260/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0101 - accuracy: 0.9972 -
val_loss: 0.5243 - val_accuracy: 0.9263
Epoch 261/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0145 - accuracy: 0.9951
- val_loss: 0.5064 - val_accuracy: 0.9272
Epoch 262/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0108 - accuracy: 0.9961
- val_loss: 0.5415 - val_accuracy: 0.9214
Epoch 263/300
53/53 [==============================] - 1s 16ms/step - loss: 0.0210 - accuracy: 0.9949
- val_loss: 0.5164 - val_accuracy: 0.9178
Epoch 264/300
53/53 [==============================] - 1s 16ms/step - loss: 0.0222 - accuracy: 0.9954
- val_loss: 0.5326 - val_accuracy: 0.9208
Epoch 265/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0153 - accuracy: 0.9960
- val_loss: 0.5726 - val_accuracy: 0.9178
Epoch 266/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0209 - accuracy: 0.9942
- val_loss: 0.5448 - val_accuracy: 0.9139
Epoch 267/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0176 - accuracy: 0.9958
- val_loss: 0.4932 - val_accuracy: 0.9257
Epoch 268/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0155 - accuracy: 0.9952
- val_loss: 0.5150 - val_accuracy: 0.9236
Epoch 269/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0113 - accuracy: 0.9967
- val_loss: 0.5103 - val_accuracy: 0.9214
Epoch 270/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0170 - accuracy: 0.9957
- val_loss: 0.5431 - val_accuracy: 0.9175
Epoch 271/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0114 - accuracy: 0.9969
- val_loss: 0.5383 - val_accuracy: 0.9224
Epoch 272/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0156 - accuracy: 0.9951
- val_loss: 0.5677 - val_accuracy: 0.9199
Epoch 273/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0184 - accuracy: 0.9943
- val_loss: 0.5685 - val_accuracy: 0.9211
Epoch 274/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0200 - accuracy: 0.9943
- val_loss: 0.5475 - val_accuracy: 0.9199
Epoch 275/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0253 - accuracy: 0.9931
- val_loss: 0.5287 - val_accuracy: 0.9151
Epoch 276/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0311 - accuracy: 0.9924
- val_loss: 0.4886 - val_accuracy: 0.9205
Epoch 277/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0195 - accuracy: 0.9936
- val_loss: 0.4961 - val_accuracy: 0.9251
Epoch 278/300
```

```
53/53 [==============================] - 1s 10ms/step - loss: 0.0144 - accuracy: 0.9955
- val_loss: 0.5380 - val_accuracy: 0.9221
Epoch 279/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0137 - accuracy: 0.9952
- val_loss: 0.5303 - val_accuracy: 0.9242
Epoch 280/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0126 - accuracy: 0.9966
- val_loss: 0.5437 - val_accuracy: 0.9190
Epoch 281/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0134 - accuracy: 0.9954
- val_loss: 0.5139 - val_accuracy: 0.9236
Epoch 282/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0153 - accuracy: 0.9963
- val_loss: 0.5235 - val_accuracy: 0.9196
Epoch 283/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0095 - accuracy: 0.9966
- val_loss: 0.5365 - val_accuracy: 0.9160
Epoch 284/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0100 - accuracy: 0.9969
- val_loss: 0.5367 - val_accuracy: 0.9227
Epoch 285/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0192 - accuracy: 0.9949
- val_loss: 0.5280 - val_accuracy: 0.9145
Epoch 286/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0181 - accuracy: 0.9942 -
val_loss: 0.5003 - val_accuracy: 0.9199
Epoch 287/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0146 - accuracy: 0.9952
- val_loss: 0.5183 - val_accuracy: 0.9211
Epoch 288/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0172 - accuracy: 0.9945
- val_loss: 0.5189 - val_accuracy: 0.9154
Epoch 289/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0145 - accuracy: 0.9952
- val_loss: 0.5438 - val_accuracy: 0.9178
Epoch 290/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0117 - accuracy: 0.9961
- val_loss: 0.5673 - val_accuracy: 0.9169
Epoch 291/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0144 - accuracy: 0.9954
- val_loss: 0.5500 - val_accuracy: 0.9175
Epoch 292/300
53/53 [==============================] - 1s 10ms/step - loss: 0.0152 - accuracy: 0.9951
- val_loss: 0.5710 - val_accuracy: 0.9148
Epoch 293/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0202 - accuracy: 0.9945 -
val_loss: 0.5903 - val_accuracy: 0.9169
Epoch 294/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0189 - accuracy: 0.9951 -
val_loss: 0.5408 - val_accuracy: 0.9214
Epoch 295/300
53/53 [==============================] - 0s 9ms/step - loss: 0.0225 - accuracy: 0.9942 -
val_loss: 0.5788 - val_accuracy: 0.9175
Epoch 296/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0186 - accuracy: 0.9948
- val_loss: 0.5675 - val_accuracy: 0.9126
Epoch 297/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0188 - accuracy: 0.9942
- val_loss: 0.5451 - val_accuracy: 0.9178
Epoch 298/300
53/53 [==============================] - 1s 11ms/step - loss: 0.0116 - accuracy: 0.9970
- val_loss: 0.5591 - val_accuracy: 0.9208
Epoch 299/300
53/53 [==============================] - 1s 12ms/step - loss: 0.0220 - accuracy: 0.9940
```

- val_loss: 0.5208 - val_accuracy: 0.9199
Epoch 300/300
53/53 [==============================] - 1s 9ms/step - loss: 0.0131 - accuracy: 0.9963 - val_loss: 0.5440 - val_accuracy: 0.9190

In [31]:
```
# evaluate model
_, accuracy = model.evaluate(x_test, y_test, batch_size=128)
```

26/26 [==============================] - 0s 3ms/step - loss: 0.5440 - accuracy: 0.9190

In [32]:
```
print("Accuracy:",accuracy) # print accuracy
```

Accuracy: 0.9190173149108887

With Deep Learning we achevied an **Accuracy of 92.84%**.

In [34]:
```
# Plot results
pd.DataFrame(history.history).plot(figsize=(12,6))
plt.show()
```