S+P_Week_3_Lesson_4_LSTM

December 6, 2020

[ ]:
```
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```

[ ]:
```
!pip install tf-nightly-2.0-preview
```

[ ]:
```
import tensorflow as tf
import numpy as np
import matplotlib.pyplot as plt
print(tf.__version__)
```

2.0.0-dev20190628

[ ]:
```
def plot_series(time, series, format="-", start=0, end=None):
    plt.plot(time[start:end], series[start:end], format)
    plt.xlabel("Time")
    plt.ylabel("Value")
    plt.grid(True)

def trend(time, slope=0):
    return slope * time

def seasonal_pattern(season_time):
    """Just an arbitrary pattern, you can change it if you wish"""
    return np.where(season_time < 0.4,
                    np.cos(season_time * 2 * np.pi),
                    1 / np.exp(3 * season_time))

def seasonality(time, period, amplitude=1, phase=0):
    """Repeats the same pattern at each period"""
```

```python
    season_time = ((time + phase) % period) / period
    return amplitude * seasonal_pattern(season_time)

def noise(time, noise_level=1, seed=None):
    rnd = np.random.RandomState(seed)
    return rnd.randn(len(time)) * noise_level

time = np.arange(4 * 365 + 1, dtype="float32")
baseline = 10
series = trend(time, 0.1)
baseline = 10
amplitude = 40
slope = 0.05
noise_level = 5

# Create the series
series = baseline + trend(time, slope) + seasonality(time, period=365, 
 ↪amplitude=amplitude)
# Update with noise
series += noise(time, noise_level, seed=42)

split_time = 1000
time_train = time[:split_time]
x_train = series[:split_time]
time_valid = time[split_time:]
x_valid = series[split_time:]

window_size = 20
batch_size = 32
shuffle_buffer_size = 1000
```

[ ]:
```python
def windowed_dataset(series, window_size, batch_size, shuffle_buffer):
  dataset = tf.data.Dataset.from_tensor_slices(series)
  dataset = dataset.window(window_size + 1, shift=1, drop_remainder=True)
  dataset = dataset.flat_map(lambda window: window.batch(window_size + 1))
  dataset = dataset.shuffle(shuffle_buffer).map(lambda window: (window[:-1], 
 ↪window[-1]))
  dataset = dataset.batch(batch_size).prefetch(1)
  return dataset
```

[ ]:
```python
tf.keras.backend.clear_session()
tf.random.set_seed(51)
np.random.seed(51)

tf.keras.backend.clear_session()
dataset = windowed_dataset(x_train, window_size, batch_size, 
 ↪shuffle_buffer_size)
```

```python
model = tf.keras.models.Sequential([
  tf.keras.layers.Lambda(lambda x: tf.expand_dims(x, axis=-1),
                      input_shape=[None]),
    tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32,␣
 ↪return_sequences=True)),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32)),
  tf.keras.layers.Dense(1),
  tf.keras.layers.Lambda(lambda x: x * 100.0)
])

lr_schedule = tf.keras.callbacks.LearningRateScheduler(
    lambda epoch: 1e-8 * 10**(epoch / 20))
optimizer = tf.keras.optimizers.SGD(lr=1e-8, momentum=0.9)
model.compile(loss=tf.keras.losses.Huber(),
              optimizer=optimizer,
              metrics=["mae"])
history = model.fit(dataset, epochs=100, callbacks=[lr_schedule])
```

```
Epoch 1/100
```

```
W0701 23:09:28.075649 139706394146688 deprecation.py:323] From
/usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/keras/optimizer_v2/optimizer_v2.py:460:
BaseResourceVariable.constraint (from
tensorflow.python.ops.resource_variable_ops) is deprecated and will be removed
in a future version.
Instructions for updating:
Apply a constraint manually following the optimizer update step.
```

```
31/31 [==============================] - 6s 184ms/step - loss: 21.4949 - mae:
22.0115
Epoch 2/100
31/31 [==============================] - 1s 38ms/step - loss: 21.1328 - mae:
21.6472
Epoch 3/100
31/31 [==============================] - 1s 38ms/step - loss: 20.7158 - mae:
21.2292
Epoch 4/100
31/31 [==============================] - 1s 37ms/step - loss: 20.2701 - mae:
20.7798
Epoch 5/100
31/31 [==============================] - 1s 38ms/step - loss: 19.7780 - mae:
20.2896
Epoch 6/100
31/31 [==============================] - 1s 37ms/step - loss: 19.1758 - mae:
19.6838
Epoch 7/100
31/31 [==============================] - 1s 37ms/step - loss: 18.2329 - mae:
```

```
18.7455
Epoch 8/100
31/31 [==============================] - 1s 37ms/step - loss: 17.4745 - mae:
17.9816
Epoch 9/100
31/31 [==============================] - 1s 36ms/step - loss: 17.1541 - mae:
17.6597
Epoch 10/100
31/31 [==============================] - 1s 39ms/step - loss: 16.8486 - mae:
17.3525
Epoch 11/100
31/31 [==============================] - 1s 38ms/step - loss: 16.5485 - mae:
17.0524
Epoch 12/100
31/31 [==============================] - 1s 37ms/step - loss: 16.2530 - mae:
16.7591
Epoch 13/100
31/31 [==============================] - 1s 36ms/step - loss: 15.9575 - mae:
16.4636
Epoch 14/100
31/31 [==============================] - 1s 36ms/step - loss: 15.6584 - mae:
16.1633
Epoch 15/100
31/31 [==============================] - 1s 36ms/step - loss: 15.3578 - mae:
15.8621
Epoch 16/100
31/31 [==============================] - 1s 36ms/step - loss: 15.0649 - mae:
15.5677
Epoch 17/100
31/31 [==============================] - 1s 37ms/step - loss: 14.7838 - mae:
15.2885
Epoch 18/100
31/31 [==============================] - 1s 37ms/step - loss: 14.5124 - mae:
15.0166
Epoch 19/100
31/31 [==============================] - 1s 38ms/step - loss: 14.2572 - mae:
14.7570
Epoch 20/100
31/31 [==============================] - 1s 37ms/step - loss: 14.0244 - mae:
14.5246
Epoch 21/100
31/31 [==============================] - 1s 38ms/step - loss: 13.8093 - mae:
14.3102
Epoch 22/100
31/31 [==============================] - 1s 38ms/step - loss: 13.5990 - mae:
14.1009
Epoch 23/100
31/31 [==============================] - 1s 36ms/step - loss: 13.3874 - mae:
```

```
13.8871
Epoch 24/100
31/31 [==============================] - 1s 37ms/step - loss: 13.1721 - mae:
13.6703
Epoch 25/100
31/31 [==============================] - 1s 36ms/step - loss: 12.9491 - mae:
13.4467
Epoch 26/100
31/31 [==============================] - 1s 38ms/step - loss: 12.7177 - mae:
13.2158
Epoch 27/100
31/31 [==============================] - 1s 37ms/step - loss: 12.4759 - mae:
12.9747
Epoch 28/100
31/31 [==============================] - 1s 38ms/step - loss: 12.2282 - mae:
12.7263
Epoch 29/100
31/31 [==============================] - 1s 38ms/step - loss: 11.9710 - mae:
12.4713
Epoch 30/100
31/31 [==============================] - 1s 37ms/step - loss: 11.7008 - mae:
12.2018
Epoch 31/100
31/31 [==============================] - 1s 37ms/step - loss: 11.3790 - mae:
11.8717
Epoch 32/100
31/31 [==============================] - 1s 38ms/step - loss: 11.2770 - mae:
11.7775
Epoch 33/100
31/31 [==============================] - 1s 37ms/step - loss: 10.5393 - mae:
11.0358
Epoch 34/100
31/31 [==============================] - 1s 37ms/step - loss: 10.9169 - mae:
11.4071
Epoch 35/100
31/31 [==============================] - 1s 37ms/step - loss: 11.1307 - mae:
11.6302
Epoch 36/100
31/31 [==============================] - 1s 37ms/step - loss: 10.6052 - mae:
11.1067
Epoch 37/100
31/31 [==============================] - 1s 38ms/step - loss: 10.0656 - mae:
10.5667
Epoch 38/100
31/31 [==============================] - 1s 37ms/step - loss: 9.5500 - mae:
10.0461
Epoch 39/100
31/31 [==============================] - 1s 37ms/step - loss: 9.0605 - mae:
```

```
9.5571
Epoch 40/100
31/31 [==============================] - 1s 39ms/step - loss: 8.6169 - mae:
9.1088
Epoch 41/100
31/31 [==============================] - 1s 37ms/step - loss: 8.1961 - mae:
8.6896
Epoch 42/100
31/31 [==============================] - 1s 39ms/step - loss: 7.8300 - mae:
8.3230
Epoch 43/100
31/31 [==============================] - 1s 38ms/step - loss: 7.5609 - mae:
8.0550
Epoch 44/100
31/31 [==============================] - 1s 37ms/step - loss: 7.3059 - mae:
7.8007
Epoch 45/100
31/31 [==============================] - 1s 38ms/step - loss: 7.0696 - mae:
7.5605
Epoch 46/100
31/31 [==============================] - 1s 38ms/step - loss: 6.8414 - mae:
7.3303
Epoch 47/100
31/31 [==============================] - 1s 37ms/step - loss: 6.6322 - mae:
7.1208
Epoch 48/100
31/31 [==============================] - 1s 38ms/step - loss: 6.4345 - mae:
6.9241
Epoch 49/100
31/31 [==============================] - 1s 38ms/step - loss: 6.2254 - mae:
6.7161
Epoch 50/100
31/31 [==============================] - 1s 36ms/step - loss: 6.0527 - mae:
6.5433
Epoch 51/100
31/31 [==============================] - 1s 37ms/step - loss: 5.8990 - mae:
6.3832
Epoch 52/100
31/31 [==============================] - 1s 37ms/step - loss: 5.7542 - mae:
6.2375
Epoch 53/100
31/31 [==============================] - 1s 37ms/step - loss: 5.6079 - mae:
6.0902
Epoch 54/100
31/31 [==============================] - 1s 38ms/step - loss: 5.4807 - mae:
5.9581
Epoch 55/100
31/31 [==============================] - 1s 36ms/step - loss: 5.3883 - mae:
```

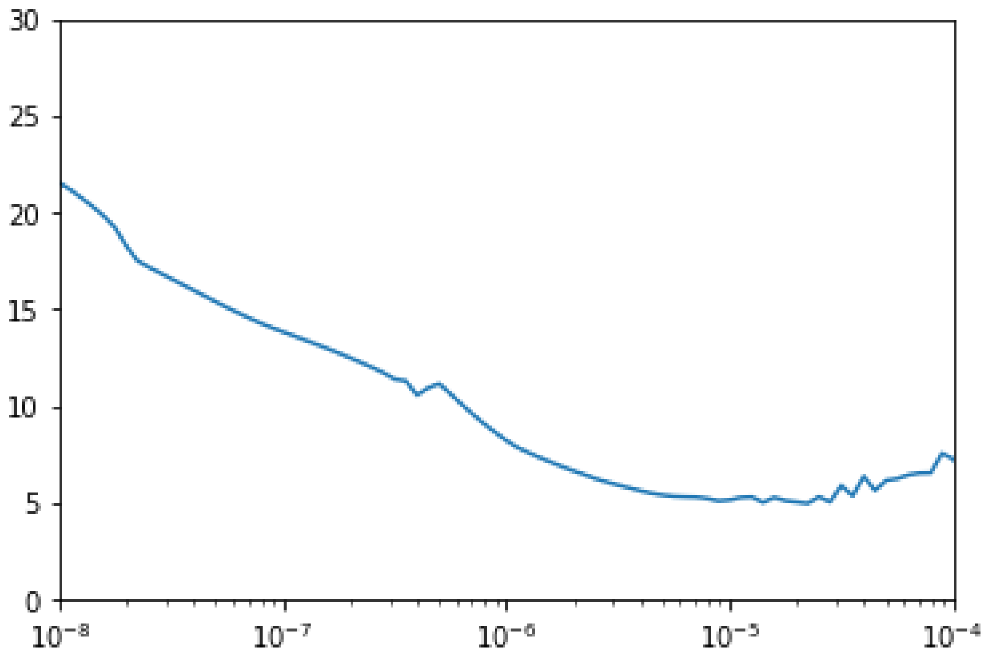
```
5.8649
Epoch 56/100
31/31 [==============================] - 1s 37ms/step - loss: 5.3283 - mae:
5.7960
Epoch 57/100
31/31 [==============================] - 1s 37ms/step - loss: 5.3062 - mae:
5.7761
Epoch 58/100
31/31 [==============================] - 1s 38ms/step - loss: 5.2953 - mae:
5.7588
Epoch 59/100
31/31 [==============================] - 1s 36ms/step - loss: 5.2223 - mae:
5.6861
Epoch 60/100
31/31 [==============================] - 1s 37ms/step - loss: 5.0937 - mae:
5.5644
Epoch 61/100
31/31 [==============================] - 1s 38ms/step - loss: 5.1471 - mae:
5.6095
Epoch 62/100
31/31 [==============================] - 1s 39ms/step - loss: 5.2782 - mae:
5.7408
Epoch 63/100
31/31 [==============================] - 1s 38ms/step - loss: 5.3021 - mae:
5.7684
Epoch 64/100
31/31 [==============================] - 1s 37ms/step - loss: 4.9985 - mae:
5.4791
Epoch 65/100
31/31 [==============================] - 1s 37ms/step - loss: 5.2652 - mae:
5.7438
Epoch 66/100
31/31 [==============================] - 1s 37ms/step - loss: 5.0887 - mae:
5.5727
Epoch 67/100
31/31 [==============================] - 1s 36ms/step - loss: 5.0244 - mae:
5.5037
Epoch 68/100
31/31 [==============================] - 1s 37ms/step - loss: 4.9528 - mae:
5.4332
Epoch 69/100
31/31 [==============================] - 1s 39ms/step - loss: 5.2934 - mae:
5.7748
Epoch 70/100
31/31 [==============================] - 1s 38ms/step - loss: 5.0257 - mae:
5.5061
Epoch 71/100
31/31 [==============================] - 1s 38ms/step - loss: 5.8698 - mae:
```

```
6.3689
Epoch 72/100
31/31 [==============================] - 1s 38ms/step - loss: 5.3336 - mae:
5.8189
Epoch 73/100
31/31 [==============================] - 1s 36ms/step - loss: 6.3428 - mae:
6.8376
Epoch 74/100
31/31 [==============================] - 1s 36ms/step - loss: 5.6116 - mae:
6.1061
Epoch 75/100
31/31 [==============================] - 1s 38ms/step - loss: 6.1446 - mae:
6.6292
Epoch 76/100
31/31 [==============================] - 1s 36ms/step - loss: 6.2236 - mae:
6.7193
Epoch 77/100
31/31 [==============================] - 1s 37ms/step - loss: 6.4386 - mae:
6.9178
Epoch 78/100
31/31 [==============================] - 1s 36ms/step - loss: 6.5088 - mae:
7.0080
Epoch 79/100
31/31 [==============================] - 1s 36ms/step - loss: 6.5152 - mae:
7.0168
Epoch 80/100
31/31 [==============================] - 1s 41ms/step - loss: 7.5090 - mae:
8.0238
Epoch 81/100
31/31 [==============================] - 1s 38ms/step - loss: 7.2540 - mae:
7.7349
Epoch 82/100
31/31 [==============================] - 1s 38ms/step - loss: 6.3301 - mae:
6.8037
Epoch 83/100
31/31 [==============================] - 1s 37ms/step - loss: 5.4483 - mae:
5.8989
Epoch 84/100
31/31 [==============================] - 1s 37ms/step - loss: 6.1204 - mae:
6.6115
Epoch 85/100
31/31 [==============================] - 1s 37ms/step - loss: 6.6871 - mae:
7.1887
Epoch 86/100
31/31 [==============================] - 1s 38ms/step - loss: 6.4184 - mae:
6.8992
Epoch 87/100
31/31 [==============================] - 1s 37ms/step - loss: 6.6237 - mae:
```

```
7.1150
Epoch 88/100
31/31 [==============================] - 1s 38ms/step - loss: 7.3721 - mae:
7.8736
Epoch 89/100
31/31 [==============================] - 1s 36ms/step - loss: 8.0184 - mae:
8.4836
Epoch 90/100
31/31 [==============================] - 1s 36ms/step - loss: 9.6776 - mae:
10.2216
Epoch 91/100
31/31 [==============================] - 1s 37ms/step - loss: 8.6603 - mae:
9.1908
Epoch 92/100
31/31 [==============================] - 1s 36ms/step - loss: 9.1711 - mae:
9.6962
Epoch 93/100
31/31 [==============================] - 1s 36ms/step - loss: 7.4648 - mae:
7.9644
Epoch 94/100
31/31 [==============================] - 1s 37ms/step - loss: 9.8468 - mae:
10.3532
Epoch 95/100
31/31 [==============================] - 1s 37ms/step - loss: 9.1915 - mae:
9.6303
Epoch 96/100
31/31 [==============================] - 1s 37ms/step - loss: 10.5476 - mae:
11.0897
Epoch 97/100
31/31 [==============================] - 1s 37ms/step - loss: 11.4537 - mae:
11.9054
Epoch 98/100
31/31 [==============================] - 1s 36ms/step - loss: 12.7645 - mae:
13.3121
Epoch 99/100
31/31 [==============================] - 1s 37ms/step - loss: 11.1958 - mae:
11.7019
Epoch 100/100
31/31 [==============================] - 1s 37ms/step - loss: 12.7021 - mae:
13.2224
```

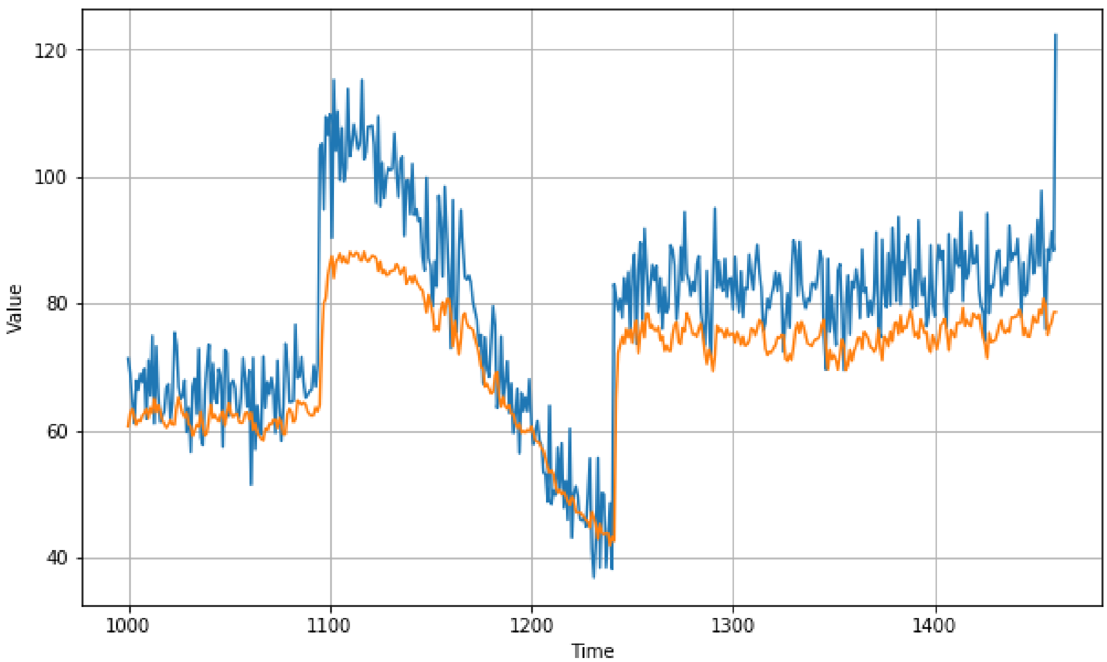
[ ]:
```
plt.semilogx(history.history["lr"], history.history["loss"])
plt.axis([1e-8, 1e-4, 0, 30])
```

[ ]:
```
[1e-08, 0.0001, 0, 30]
```



[ ]:
```
tf.keras.backend.clear_session()
tf.random.set_seed(51)
np.random.seed(51)

tf.keras.backend.clear_session()
dataset = windowed_dataset(x_train, window_size, batch_size,␣
↪shuffle_buffer_size)

model = tf.keras.models.Sequential([
  tf.keras.layers.Lambda(lambda x: tf.expand_dims(x, axis=-1),
                      input_shape=[None]),
   tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32,␣
↪return_sequences=True)),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32)),
  tf.keras.layers.Dense(1),
  tf.keras.layers.Lambda(lambda x: x * 100.0)
])


model.compile(loss="mse", optimizer=tf.keras.optimizers.SGD(lr=1e-5, momentum=0.
↪9),metrics=["mae"])
history = model.fit(dataset,epochs=500,verbose=0)
```

[ ]:
```
forecast = []
results = []
for time in range(len(series) - window_size):
  forecast.append(model.predict(series[time:time + window_size][np.newaxis]))

forecast = forecast[split_time-window_size:]
results = np.array(forecast)[:, 0, 0]


plt.figure(figsize=(10, 6))

plot_series(time_valid, x_valid)
plot_series(time_valid, results)
```



[ ]:
```
tf.keras.metrics.mean_absolute_error(x_valid, results).numpy()
```

[ ]: 8.514286

[ ]:
```
import matplotlib.image  as mpimg
import matplotlib.pyplot as plt

#-----------------------------------------------------------
# Retrieve a list of list results on training and test data
# sets for each training epoch
#-----------------------------------------------------------
```

```
mae=history.history['mae']
loss=history.history['loss']

epochs=range(len(loss)) # Get number of epochs

#------------------------------------------------
# Plot MAE and Loss
#------------------------------------------------
plt.plot(epochs, mae, 'r')
plt.plot(epochs, loss, 'b')
plt.title('MAE and Loss')
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend(["MAE", "Loss"])

plt.figure()

epochs_zoom = epochs[200:]
mae_zoom = mae[200:]
loss_zoom = loss[200:]

#------------------------------------------------
# Plot Zoomed MAE and Loss
#------------------------------------------------
plt.plot(epochs_zoom, mae_zoom, 'r')
plt.plot(epochs_zoom, loss_zoom, 'b')
plt.title('MAE and Loss')
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.legend(["MAE", "Loss"])

plt.figure()
```

```
---------------------------------------------------------------------------
KeyError                                  Traceback (most recent call last)
<ipython-input-13-0d8269471fd6> in <module>()
      6 # sets for each training epoch
      7 #------------------------------------------------------------
----> 8 mae=history.history['mae']
      9 loss=history.history['loss']
     10 

KeyError: 'mae'
```

[ ]:
```
tf.keras.backend.clear_session()
```

```
dataset = windowed_dataset(x_train, window_size, batch_size,␣
↪shuffle_buffer_size)

model = tf.keras.models.Sequential([
  tf.keras.layers.Lambda(lambda x: tf.expand_dims(x, axis=-1),
                      input_shape=[None]),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32,␣
↪return_sequences=True)),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32)),
  tf.keras.layers.Dense(1),
  tf.keras.layers.Lambda(lambda x: x * 100.0)
])


model.compile(loss="mse", optimizer=tf.keras.optimizers.SGD(lr=1e-6, momentum=0.
↪9))
model.fit(dataset,epochs=100, verbose=0)
```

[ ]:
```
tf.keras.backend.clear_session()
dataset = windowed_dataset(x_train, window_size, batch_size,␣
↪shuffle_buffer_size)

model = tf.keras.models.Sequential([
  tf.keras.layers.Lambda(lambda x: tf.expand_dims(x, axis=-1),
                      input_shape=[None]),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32,␣
↪return_sequences=True)),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32,␣
↪return_sequences=True)),
  tf.keras.layers.Bidirectional(tf.keras.layers.LSTM(32)),
  tf.keras.layers.Dense(1),
  tf.keras.layers.Lambda(lambda x: x * 100.0)
])


model.compile(loss="mse", optimizer=tf.keras.optimizers.SGD(lr=1e-6, momentum=0.
↪9))
model.fit(dataset,epochs=100)
```