CFRM 421/521, Spring 2022

[Insert your name here]

Homework 4

- **Due: Tuesday, May 31, 2022, 11:59 PM**
- Total marks: 47
- Late submissions are allowed, but a 20% penalty per day applies. Your last submission is considered for calculating the penalty.
- Use this Jupyter notebook as a template for your solutions. **Your solution must be submitted as one Jupyter notebook on Canvas and one PDF file on Gradescope.** The notebook must be already run, that is, make sure that you have run all your code, save the notebook, and then when you reopen the notebook, checked that all output appears as expected. You are allowed to use code from the textbook, textbook website, or lecture notes.

1. A regression MLP [10 marks]

Consider the California housing data from Homework 1 using the same training and test set there. Here, we split off 20% of the training set as a validation set, and keep the remaining 80% as the actual training set. The following code replicates the preprocessing of the dataset from Homework 1, creating the training set `X_train` , `y_train` , the validation set `X_valid` , `y_valid` and the test set `X_test` , `y_test` . The target variable has been divided by 100,000.

In [1]:
```
pip install tensorflow
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-whe
els/public/simple/
Requirement already satisfied: tensorflow in /usr/local/lib/python3.7/dist-packa
ges (2.8.0+zzzcolab20220506162203)
Requirement already satisfied: h5py>=2.9.0 in /usr/local/lib/python3.7/dist-pack
ages (from tensorflow) (3.1.0)
Collecting tf-estimator-nightly==2.8.0.dev2021122109
  Downloading tf_estimator_nightly-2.8.0.dev2021122109-py2.py3-none-any.whl (462
kB)
     |████████████████████████████████| 462 kB 5.2 MB/s
Requirement already satisfied: six>=1.12.0 in /usr/local/lib/python3.7/dist-pack
ages (from tensorflow) (1.15.0)
Requirement already satisfied: wrapt>=1.11.0 in /usr/local/lib/python3.7/dist-pa
ckages (from tensorflow) (1.14.1)
Requirement already satisfied: keras<2.9,>=2.8.0rc0 in /usr/local/lib/python3.7/
dist-packages (from tensorflow) (2.8.0)
```

```
Requirement already satisfied: google-pasta>=0.1.1 in /usr/local/lib/python3.7/d
ist-packages (from tensorflow) (0.2.0)
Requirement already satisfied: absl-py>=0.4.0 in /usr/local/lib/python3.7/dist-p
ackages (from tensorflow) (1.0.0)
Requirement already satisfied: protobuf>=3.9.2 in /usr/local/lib/python3.7/dist-
packages (from tensorflow) (3.17.3)
Requirement already satisfied: gast>=0.2.1 in /usr/local/lib/python3.7/dist-pack
ages (from tensorflow) (0.5.3)
Requirement already satisfied: tensorboard<2.9,>=2.8 in /usr/local/lib/python3.
7/dist-packages (from tensorflow) (2.8.0)
Requirement already satisfied: typing-extensions>=3.6.6 in /usr/local/lib/python
3.7/dist-packages (from tensorflow) (4.2.0)
Requirement already satisfied: flatbuffers>=1.12 in /usr/local/lib/python3.7/dis
t-packages (from tensorflow) (2.0)
Requirement already satisfied: termcolor>=1.1.0 in /usr/local/lib/python3.7/dist
-packages (from tensorflow) (1.1.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in /usr/local/lib/python3.7/d
ist-packages (from tensorflow) (1.46.1)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in /usr/loca
l/lib/python3.7/dist-packages (from tensorflow) (0.26.0)
Requirement already satisfied: numpy>=1.20 in /usr/local/lib/python3.7/dist-pack
ages (from tensorflow) (1.21.6)
Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-packa
ges (from tensorflow) (57.4.0)
Requirement already satisfied: libclang>=9.0.1 in /usr/local/lib/python3.7/dist-
packages (from tensorflow) (14.0.1)
Requirement already satisfied: astunparse>=1.6.0 in /usr/local/lib/python3.7/dis
t-packages (from tensorflow) (1.6.3)
Requirement already satisfied: opt-einsum>=2.3.2 in /usr/local/lib/python3.7/dis
t-packages (from tensorflow) (3.3.0)
Requirement already satisfied: keras-preprocessing>=1.1.1 in /usr/local/lib/pyth
on3.7/dist-packages (from tensorflow) (1.1.2)
Requirement already satisfied: wheel<1.0,>=0.23.0 in /usr/local/lib/python3.7/di
st-packages (from astunparse>=1.6.0->tensorflow) (0.37.1)
Requirement already satisfied: cached-property in /usr/local/lib/python3.7/dist-
packages (from h5py>=2.9.0->tensorflow) (1.5.2)
Requirement already satisfied: requests<3,>=2.21.0 in /usr/local/lib/python3.7/d
ist-packages (from tensorboard<2.9,>=2.8->tensorflow) (2.23.0)
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in /usr/local/li
b/python3.7/dist-packages (from tensorboard<2.9,>=2.8->tensorflow) (0.4.6)
Requirement already satisfied: tensorboard-data-server<0.7.0,>=0.6.0 in /usr/loc
al/lib/python3.7/dist-packages (from tensorboard<2.9,>=2.8->tensorflow) (0.6.1)
Requirement already satisfied: werkzeug>=0.11.15 in /usr/local/lib/python3.7/dis
t-packages (from tensorboard<2.9,>=2.8->tensorflow) (1.0.1)
Requirement already satisfied: google-auth<3,>=1.6.3 in /usr/local/lib/python3.
7/dist-packages (from tensorboard<2.9,>=2.8->tensorflow) (1.35.0)
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in /usr/local/lib/p
ython3.7/dist-packages (from tensorboard<2.9,>=2.8->tensorflow) (1.8.1)
Requirement already satisfied: markdown>=2.6.8 in /usr/local/lib/python3.7/dist-
packages (from tensorboard<2.9,>=2.8->tensorflow) (3.3.7)
Requirement already satisfied: cachetools<5.0,>=2.0.0 in /usr/local/lib/python3.
7/dist-packages (from google-auth<3,>=1.6.3->tensorboard<2.9,>=2.8->tensorflow)
(4.2.4)
Requirement already satisfied: pyasn1-modules>=0.2.1 in /usr/local/lib/python3.
7/dist-packages (from google-auth<3,>=1.6.3->tensorboard<2.9,>=2.8->tensorflow)
(0.2.8)
Requirement already satisfied: rsa<5,>=3.1.4 in /usr/local/lib/python3.7/dist-pa
ckages (from google-auth<3,>=1.6.3->tensorboard<2.9,>=2.8->tensorflow) (4.8)
Requirement already satisfied: requests-oauthlib>=0.7.0 in /usr/local/lib/python
3.7/dist-packages (from google-auth-oauthlib<0.5,>=0.4.1->tensorboard<2.9,>=2.8-
>tensorflow) (1.3.1)
Requirement already satisfied: importlib-metadata>=4.4 in /usr/local/lib/python
3.7/dist-packages (from markdown>=2.6.8->tensorboard<2.9,>=2.8->tensorflow) (4.1
1.3)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-packag
```

```
es (from importlib-metadata>=4.4->markdown>=2.6.8->tensorboard<2.9,>=2.8->tensor
flow) (3.8.0)
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in /usr/local/lib/python3.7/
dist-packages (from pyasn1-modules>=0.2.1->google-auth<3,>=1.6.3->tensorboard<2.
9,>=2.8->tensorflow) (0.4.8)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.7/di
st-packages (from requests<3,>=2.21.0->tensorboard<2.9,>=2.8->tensorflow) (2022.
5.18.1)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /usr/l
ocal/lib/python3.7/dist-packages (from requests<3,>=2.21.0->tensorboard<2.9,>=2.
8->tensorflow) (1.24.3)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.7/dis
t-packages (from requests<3,>=2.21.0->tensorboard<2.9,>=2.8->tensorflow) (3.0.4)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/dist-pac
kages (from requests<3,>=2.21.0->tensorboard<2.9,>=2.8->tensorflow) (2.10)
Requirement already satisfied: oauthlib>=3.0.0 in /usr/local/lib/python3.7/dist-
packages (from requests-oauthlib>=0.7.0->google-auth-oauthlib<0.5,>=0.4.1->tenso
rboard<2.9,>=2.8->tensorflow) (3.2.0)
Installing collected packages: tf-estimator-nightly
Successfully installed tf-estimator-nightly-2.8.0.dev2021122109
```

In [1]:

```python
import numpy as np
import pandas as pd
import tensorflow as tf
import tensorflow.keras as keras
```

In [2]:

```python
from sklearn.pipeline import Pipeline
from sklearn.impute import SimpleImputer
from sklearn.compose import ColumnTransformer
from sklearn.preprocessing import StandardScaler, OneHotEncoder
from sklearn.model_selection import StratifiedShuffleSplit

import os
import tarfile
from six.moves import urllib

HOUSING_PATH = os.path.join("datasets", "housing")

def fetch_housing_data(housing_url, housing_path=HOUSING_PATH):
    if not os.path.isdir(housing_path):
        os.makedirs(housing_path)
    tgz_path = os.path.join(housing_path, "housing.tgz")
    urllib.request.urlretrieve(housing_url, tgz_path)
    housing_tgz = tarfile.open(tgz_path)
    housing_tgz.extractall(path=housing_path)
    housing_tgz.close()

def load_housing_data(housing_path=HOUSING_PATH):
    csv_path = os.path.join(housing_path, "housing.csv")
    return pd.read_csv(csv_path)

HOUSING_URL = ("https://raw.githubusercontent.com/ageron/"+
               "handson-ml2/master/datasets/housing/housing.tgz")
fetch_housing_data(HOUSING_URL)
data = load_housing_data()

data["income_cat"] = np.ceil(data["median_income"] / 1.5)
data["income_cat"].where(data["income_cat"] < 5, 5.0, inplace=True)
split = StratifiedShuffleSplit(n_splits=1, test_size=0.2, random_state=42)
for train_index, test_index in split.split(data, data["income_cat"]):
    strat_train_set = data.loc[train_index]
```

```
    strat_test_set = data.loc[test_index]

# Split the traning set into training and validation
split2 = StratifiedShuffleSplit(n_splits=1, test_size=0.2, random_state=42)
for train_index2, valid_index in split2.split(strat_train_set, strat_train_set["
    strat_train2_set = strat_train_set.iloc[train_index2]
    strat_valid_set = strat_train_set.iloc[valid_index]

strat_train_set = strat_train2_set.copy().drop("income_cat", axis=1)
strat_valid_set = strat_valid_set.copy().drop("income_cat", axis=1)
strat_test_set = strat_test_set.copy().drop("income_cat", axis=1)

X_raw = strat_train_set.drop("median_house_value", axis=1)
y_train = strat_train_set["median_house_value"].copy()/100000

num_pipeline = Pipeline([
        ('imputer', SimpleImputer(strategy="median")),
        ('std_scaler', StandardScaler()),
    ])
num_features = X_raw.drop("ocean_proximity", axis=1)
num_attribs = list(num_features)
cat_attribs = ["ocean_proximity"]
full_pipeline = ColumnTransformer([
        ("num", num_pipeline, num_attribs),
        ("cat", OneHotEncoder(), cat_attribs),
    ])

# Apply the pipeline to the training set
X_train = full_pipeline.fit_transform(X_raw)

# Apply the pipeline to the validation set
X_valid_raw = strat_valid_set.drop("median_house_value", axis=1)
y_valid = strat_valid_set["median_house_value"].copy()/100000
X_valid = full_pipeline.transform(X_valid_raw)

# Apply the pipeline to the validation set
X_test_raw = strat_test_set.drop("median_house_value", axis=1)
y_test = strat_test_set["median_house_value"].copy()/100000
X_test = full_pipeline.transform(X_test_raw)
```

(a) [4 marks]

Use `tensorflow.keras` to train a regression MLP with one hidden layer of 50 ReLU neurons. For the output layer, try both a ReLU activation function and no activation function (which is equivalent to the identity function). Explain which choice is better. Use the appropriate weight initialization. Use the Nadam optimizer. Train for 30 epochs, and report the mean squared error on the validation set.

Hint: In the `.compile()` method, use `loss="mse"`.

[Add your solution here]

In [13]:
```
from tensorflow.keras import Sequential, layers
mlp = Sequential([layers.Dense(50, activation="relu",
                               kernel_initializer="he_normal"),
                  layers.Dense(1, activation="relu")])
```

```
mlp.compile(optimizer='Nadam',
            loss='mse')
```

In [14]:
```
mlp.fit(X_train, y_train, epochs=30,
          validation_data=(X_valid, y_valid))
```

```
Epoch 1/30
413/413 [==============================] - 2s 2ms/step - loss: 1.1045 - val_los
s: 0.5694
Epoch 2/30
413/413 [==============================] - 1s 2ms/step - loss: 0.4853 - val_los
s: 0.4686
Epoch 3/30
413/413 [==============================] - 1s 2ms/step - loss: 0.4348 - val_los
s: 0.4397
Epoch 4/30
413/413 [==============================] - 1s 2ms/step - loss: 0.4138 - val_los
s: 0.4175
Epoch 5/30
413/413 [==============================] - 1s 2ms/step - loss: 0.4007 - val_los
s: 0.4044
Epoch 6/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3891 - val_los
s: 0.3949
Epoch 7/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3801 - val_los
s: 0.3879
Epoch 8/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3734 - val_los
s: 0.3795
Epoch 9/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3676 - val_los
s: 0.3738
Epoch 10/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3622 - val_los
s: 0.3694
Epoch 11/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3572 - val_los
s: 0.3767
Epoch 12/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3552 - val_los
s: 0.3660
Epoch 13/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3512 - val_los
s: 0.3599
Epoch 14/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3479 - val_los
s: 0.3553
Epoch 15/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3453 - val_los
s: 0.3590
Epoch 16/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3434 - val_los
s: 0.3537
Epoch 17/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3418 - val_los
s: 0.3597
Epoch 18/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3393 - val_los
s: 0.3531
Epoch 19/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3379 - val_los
s: 0.3519
Epoch 20/30
```

```
413/413 [==============================] - 1s 2ms/step - loss: 0.3356 - val_los
s: 0.3544
Epoch 21/30
413/413 [==============================] - 1s 3ms/step - loss: 0.3343 - val_los
s: 0.3524
Epoch 22/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3325 - val_los
s: 0.3486
Epoch 23/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3320 - val_los
s: 0.3454
Epoch 24/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3304 - val_los
s: 0.3451
Epoch 25/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3284 - val_los
s: 0.3421
Epoch 26/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3282 - val_los
s: 0.3417
Epoch 27/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3260 - val_los
s: 0.3422
Epoch 28/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3250 - val_los
s: 0.3454
Epoch 29/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3240 - val_los
s: 0.3429
Epoch 30/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3230 - val_los
s: 0.3379
```

Out[14]:

```
<keras.callbacks.History at 0x7f99c125f390>
```

In [16]:

```
mse_act = mlp.evaluate(X_valid, y_valid)
print(mse_act)
```

```
104/104 [==============================] - 0s 1ms/step - loss: 0.3379
0.3379059135913849
```

As using ReLU activation function, the MSE is 0.3379059135913849 .

In [17]:

```
from tensorflow.keras import Sequential, layers
mlp2 = Sequential([
    layers.Dense(50, activation="relu",
                 kernel_initializer="he_normal"),
    layers.Dense(1, activation= None )
])
```

In [18]:

```
mlp2.compile(optimizer='Nadam',
            loss='mse')
mlp2.fit(X_train, y_train,
            epochs=30,validation_data=(X_valid, y_valid))
```

```
Epoch 1/30
413/413 [==============================] - 2s 2ms/step - loss: 1.1334 - val_los
s: 0.5339
Epoch 2/30
413/413 [==============================] - 1s 2ms/step - loss: 0.4475 - val_los
s: 0.4407
Epoch 3/30
413/413 [==============================] - 1s 2ms/step - loss: 0.4061 - val_los
s: 0.4178
```

```
Epoch 4/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3891 - val_los
s: 0.3980
Epoch 5/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3779 - val_los
s: 0.3849
Epoch 6/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3691 - val_los
s: 0.3803
Epoch 7/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3622 - val_los
s: 0.3705
Epoch 8/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3568 - val_los
s: 0.3662
Epoch 9/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3533 - val_los
s: 0.3648
Epoch 10/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3503 - val_los
s: 0.3605
Epoch 11/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3467 - val_los
s: 0.3618
Epoch 12/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3433 - val_los
s: 0.3560
Epoch 13/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3406 - val_los
s: 0.3539
Epoch 14/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3397 - val_los
s: 0.3578
Epoch 15/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3368 - val_los
s: 0.3483
Epoch 16/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3347 - val_los
s: 0.3482
Epoch 17/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3333 - val_los
s: 0.3463
Epoch 18/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3309 - val_los
s: 0.3468
Epoch 19/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3289 - val_los
s: 0.3445
Epoch 20/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3277 - val_los
s: 0.3430
Epoch 21/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3271 - val_los
s: 0.3459
Epoch 22/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3251 - val_los
s: 0.3452
Epoch 23/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3239 - val_los
s: 0.3402
Epoch 24/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3213 - val_los
s: 0.3424
Epoch 25/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3213 - val_los
```

```
s: 0.3385
Epoch 26/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3210 - val_los
s: 0.3363
Epoch 27/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3184 - val_los
s: 0.3393
Epoch 28/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3179 - val_los
s: 0.3373
Epoch 29/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3169 - val_los
s: 0.3350
Epoch 30/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3161 - val_los
s: 0.3360
```

Out[18]:
```
<keras.callbacks.History at 0x7f99be5c4110>
```

In [19]:
```
mse_non_act = mlp2.evaluate(X_valid, y_valid)
print(mse_non_act)
```

```
104/104 [==============================] - 0s 1ms/step - loss: 0.3360
0.3359699845314026
```

As using ReLU non-activation function, the MSE of test set is 0.3359699845314026.

Conclusion: The MSE of outlayer with no activation function and with activation function are very close. The outlayer with no activation function has smaller MSE.

(b) [5 marks]

Read the section "Fine-Tuning Neural Network Hyperparameters" in the textbook and the corresponding section in the Jupyter notebook on the textbook website. Then use a randomized search to search for the best number of hidden layers, neurons per hidden layer, and learning rate. For the randomized search use 3-fold CV, with 10 iterations, with the number of hidden layers uniformly sampled from $\{0, 1, 2, 3\}$, the number of neurons per layer uniformly from $\{1, 2, \ldots, 100\}$, and the learning rate from the distribution `reciprocal(3e-4, 3e-2)` . Use early stopping with `patience=10` .

[Add your solution here]

In [20]:
```
def build_model(n_hidden, n_neurons, learning_rate, input_shape=[13]):
    model = keras.models.Sequential()
    model.add(keras.layers.InputLayer(input_shape=input_shape))
    for layer in range(n_hidden):
        model.add(keras.layers.Dense(n_neurons, activation="relu"))
    model.add(keras.layers.Dense(1))
    optimizer = keras.optimizers.SGD(learning_rate=learning_rate)
    model.compile(loss="mse", optimizer=optimizer)
    return model
```

In [21]:
```
keras_reg = keras.wrappers.scikit_learn.KerasRegressor(build_model)
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:1: DeprecationWarni
ng: KerasRegressor is deprecated, use Sci-Keras (https://github.com/adriangb/sci
keras) instead. See https://www.adriangb.com/scikeras/stable/migration.html for
```

```
help migrating.
  """Entry point for launching an IPython kernel.
```

In [22]:

```python
from scipy.stats import reciprocal
from sklearn.model_selection import RandomizedSearchCV

param_distribs = {
    "n_hidden": [0, 1, 2, 3],
    "n_neurons": np.arange(1, 101).tolist(),
    "learning_rate": reciprocal(3e-4, 3e-2).rvs(1000).tolist(),
}

rnd_search_cv = RandomizedSearchCV(keras_reg, param_distribs, n_iter=10, cv=3, v
rnd_search_cv.fit(X_train, y_train, epochs=30,
                  validation_data=(X_valid, y_valid),
                  callbacks=[keras.callbacks.EarlyStopping(patience=10)])
```

```
Fitting 3 folds for each of 10 candidates, totalling 30 fits
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6521 - val_los
s: 0.4759
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4393 - val_los
s: 0.4373
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4107 - val_los
s: 0.4161
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3959 - val_los
s: 0.4018
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3869 - val_los
s: 0.3908
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3809 - val_los
s: 0.3834
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3738 - val_los
s: 0.3818
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3689 - val_los
s: 0.4039
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3660 - val_los
s: 0.3704
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3622 - val_los
s: 0.3737
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3603 - val_los
s: 0.3621
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3567 - val_los
s: 0.3622
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3537 - val_los
s: 0.3687
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3523 - val_los
s: 0.3854
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3498 - val_los
s: 0.3597
Epoch 16/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.3488 - val_los
s: 0.3719
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3460 - val_los
s: 0.3713
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3450 - val_los
s: 0.3500
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3438 - val_los
s: 0.3748
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3417 - val_los
s: 0.3476
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3409 - val_los
s: 0.3473
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3386 - val_los
s: 0.3799
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3387 - val_los
s: 0.3577
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3358 - val_los
s: 0.3676
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3347 - val_los
s: 0.3394
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3323 - val_los
s: 0.3548
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3322 - val_los
s: 0.3406
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3331 - val_los
s: 0.3500
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3303 - val_los
s: 0.3451
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3286 - val_los
s: 0.3373
138/138 [==============================] - 0s 1ms/step - loss: 0.3389
[CV] END learning_rate=0.01454409005200296, n_hidden=1, n_neurons=94; total time
=  17.5s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6289 - val_los
s: 0.4796
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4265 - val_los
s: 0.4353
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4013 - val_los
s: 0.4242
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3878 - val_los
s: 0.4074
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3772 - val_los
s: 0.3932
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3724 - val_los
s: 0.3865
```

```
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3667 - val_los
s: 0.3865
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3613 - val_los
s: 0.3853
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3592 - val_los
s: 0.3873
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3536 - val_los
s: 0.3846
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3509 - val_los
s: 0.3705
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3483 - val_los
s: 0.3624
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3440 - val_los
s: 0.3952
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3417 - val_los
s: 0.4016
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3398 - val_los
s: 0.3619
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3363 - val_los
s: 0.3851
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3364 - val_los
s: 0.3971
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3348 - val_los
s: 0.3550
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3322 - val_los
s: 0.3817
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3315 - val_los
s: 0.3493
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3310 - val_los
s: 0.3679
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3273 - val_los
s: 0.3529
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3265 - val_los
s: 0.3578
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3248 - val_los
s: 0.3482
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3263 - val_los
s: 0.3601
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3225 - val_los
s: 0.3697
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3221 - val_los
s: 0.3465
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3220 - val_los
```

```
s: 0.4361
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3216 - val_los
s: 0.3622
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3194 - val_los
s: 0.3409
138/138 [==============================] - 0s 1ms/step - loss: 0.3464
[CV] END learning_rate=0.01454409005200296, n_hidden=1, n_neurons=94; total time
=  17.5s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.6387 - val_los
s: 0.5000
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4473 - val_los
s: 0.4467
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4206 - val_los
s: 0.4240
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4068 - val_los
s: 0.4132
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3978 - val_los
s: 0.4000
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3899 - val_los
s: 0.4063
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3850 - val_los
s: 0.3886
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3804 - val_los
s: 0.3873
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3753 - val_los
s: 0.3803
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3697 - val_los
s: 0.3728
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3654 - val_los
s: 0.3819
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3642 - val_los
s: 0.3681
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3618 - val_los
s: 0.3720
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3588 - val_los
s: 0.3707
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3558 - val_los
s: 0.3748
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3549 - val_los
s: 0.3703
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3524 - val_los
s: 0.3647
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3504 - val_los
s: 0.3565
Epoch 19/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.3474 - val_los
s: 0.3809
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3458 - val_los
s: 0.3853
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3444 - val_los
s: 0.3496
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3427 - val_los
s: 0.3763
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3414 - val_los
s: 0.3754
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3396 - val_los
s: 0.3571
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3382 - val_los
s: 0.3580
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3376 - val_los
s: 0.3640
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3360 - val_los
s: 0.3468
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3346 - val_los
s: 0.3508
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3323 - val_los
s: 0.3609
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3325 - val_los
s: 0.3464
138/138 [==============================] - 0s 1ms/step - loss: 0.3365
[CV] END learning_rate=0.01454409005200296, n_hidden=1, n_neurons=94; total time
=  17.8s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 5.1958 - val_los
s: 3.9815
Epoch 2/30
276/276 [==============================] - 0s 2ms/step - loss: 3.2670 - val_los
s: 2.6000
Epoch 3/30
276/276 [==============================] - 0s 2ms/step - loss: 2.1927 - val_los
s: 1.8039
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 1.5634 - val_los
s: 1.3295
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 1.1839 - val_los
s: 1.0417
Epoch 6/30
276/276 [==============================] - 0s 2ms/step - loss: 0.9517 - val_los
s: 0.8653
Epoch 7/30
276/276 [==============================] - 0s 2ms/step - loss: 0.8079 - val_los
s: 0.7567
Epoch 8/30
276/276 [==============================] - 0s 2ms/step - loss: 0.7180 - val_los
s: 0.6885
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6607 - val_los
s: 0.6458
```

```
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6240 - val_los
s: 0.6183
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5997 - val_los
s: 0.6004
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5835 - val_los
s: 0.5884
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5721 - val_los
s: 0.5799
Epoch 14/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5639 - val_los
s: 0.5737
Epoch 15/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5576 - val_los
s: 0.5690
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5527 - val_los
s: 0.5651
Epoch 17/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5487 - val_los
s: 0.5619
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5454 - val_los
s: 0.5592
Epoch 19/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5424 - val_los
s: 0.5568
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5399 - val_los
s: 0.5545
Epoch 21/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5375 - val_los
s: 0.5524
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5354 - val_los
s: 0.5506
Epoch 23/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5334 - val_los
s: 0.5488
Epoch 24/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5315 - val_los
s: 0.5471
Epoch 25/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5298 - val_los
s: 0.5454
Epoch 26/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5282 - val_los
s: 0.5439
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5266 - val_los
s: 0.5424
Epoch 28/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5252 - val_los
s: 0.5410
Epoch 29/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5238 - val_los
s: 0.5397
Epoch 30/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5225 - val_los
s: 0.5384
138/138 [==============================] - 0s 1ms/step - loss: 0.4966
[CV] END learning_rate=0.000366880691774657, n_hidden=0, n_neurons=59; total tim
```

```
e=  15.7s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 4.3282 - val_los
s: 3.4604
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 2.8899 - val_los
s: 2.4102
Epoch 3/30
276/276 [==============================] - 0s 2ms/step - loss: 2.0531 - val_los
s: 1.7827
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 1.5476 - val_los
s: 1.3961
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 1.2333 - val_los
s: 1.1525
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 1.0336 - val_los
s: 0.9964
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.9042 - val_los
s: 0.8934
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8178 - val_los
s: 0.8235
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7584 - val_los
s: 0.7749
Epoch 10/30
276/276 [==============================] - 0s 2ms/step - loss: 0.7167 - val_los
s: 0.7398
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6860 - val_los
s: 0.7134
Epoch 12/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6626 - val_los
s: 0.6927
Epoch 13/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6439 - val_los
s: 0.6761
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6288 - val_los
s: 0.6623
Epoch 15/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6161 - val_los
s: 0.6506
Epoch 16/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6052 - val_los
s: 0.6402
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5956 - val_los
s: 0.6310
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5870 - val_los
s: 0.6228
Epoch 19/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5793 - val_los
s: 0.6153
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5723 - val_los
s: 0.6083
Epoch 21/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5658 - val_los
s: 0.6020
Epoch 22/30
```

```
276/276 [==============================] - 0s 2ms/step - loss: 0.5599 - val_los
s: 0.5960
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5544 - val_los
s: 0.5905
Epoch 24/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5493 - val_los
s: 0.5853
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5445 - val_los
s: 0.5803
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5401 - val_los
s: 0.5758
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5360 - val_los
s: 0.5716
Epoch 28/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5321 - val_los
s: 0.5675
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5285 - val_los
s: 0.5637
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5251 - val_los
s: 0.5601
138/138 [==============================] - 0s 1ms/step - loss: 0.5608
[CV] END learning_rate=0.000366880691774657, n_hidden=0, n_neurons=59; total tim
e=  16.1s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 6.5460 - val_los
s: 4.9611
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 3.9918 - val_los
s: 3.1427
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 2.5859 - val_los
s: 2.1091
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 1.7792 - val_los
s: 1.5092
Epoch 5/30
276/276 [==============================] - 0s 2ms/step - loss: 1.3072 - val_los
s: 1.1550
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 1.0271 - val_los
s: 0.9429
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8580 - val_los
s: 0.8152
Epoch 8/30
276/276 [==============================] - 0s 2ms/step - loss: 0.7549 - val_los
s: 0.7363
Epoch 9/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6904 - val_los
s: 0.6863
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6489 - val_los
s: 0.6539
Epoch 11/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6212 - val_los
s: 0.6317
Epoch 12/30
276/276 [==============================] - 0s 2ms/step - loss: 0.6020 - val_los
s: 0.6161
```

```
Epoch 13/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5880 - val_los
s: 0.6043
Epoch 14/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5772 - val_los
s: 0.5949
Epoch 15/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5685 - val_los
s: 0.5871
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5612 - val_los
s: 0.5806
Epoch 17/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5550 - val_los
s: 0.5748
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5496 - val_los
s: 0.5696
Epoch 19/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5446 - val_los
s: 0.5649
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5401 - val_los
s: 0.5605
Epoch 21/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5361 - val_los
s: 0.5565
Epoch 22/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5323 - val_los
s: 0.5529
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5289 - val_los
s: 0.5494
Epoch 24/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5257 - val_los
s: 0.5464
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5227 - val_los
s: 0.5434
Epoch 26/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5199 - val_los
s: 0.5406
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5174 - val_los
s: 0.5381
Epoch 28/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5150 - val_los
s: 0.5356
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5127 - val_los
s: 0.5333
Epoch 30/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5107 - val_los
s: 0.5312
138/138 [==============================] - 0s 1ms/step - loss: 0.5185
[CV] END learning_rate=0.000366880691774657, n_hidden=0, n_neurons=59; total tim
e=  16.0s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 3.3625 - val_los
s: 1.3437
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.0225 - val_los
s: 0.9073
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8235 - val_los
```

```
s: 0.7867
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7271 - val_los
s: 0.7142
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6649 - val_los
s: 0.6632
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6218 - val_los
s: 0.6262
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5901 - val_los
s: 0.6000
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5675 - val_los
s: 0.5787
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5507 - val_los
s: 0.5626
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5371 - val_los
s: 0.5502
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5263 - val_los
s: 0.5385
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5170 - val_los
s: 0.5292
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5092 - val_los
s: 0.5217
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5020 - val_los
s: 0.5149
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4962 - val_los
s: 0.5078
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4905 - val_los
s: 0.5026
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4854 - val_los
s: 0.4968
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4807 - val_los
s: 0.4922
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4767 - val_los
s: 0.4884
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4726 - val_los
s: 0.4843
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4691 - val_los
s: 0.4815
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4656 - val_los
s: 0.4778
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4624 - val_los
s: 0.4747
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4594 - val_los
s: 0.4719
Epoch 25/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.4564 - val_los
s: 0.4683
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4539 - val_los
s: 0.4653
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4512 - val_los
s: 0.4628
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4487 - val_los
s: 0.4605
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4461 - val_los
s: 0.4580
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4440 - val_los
s: 0.4559
138/138 [==============================] - 0s 1ms/step - loss: 0.4283
[CV] END learning_rate=0.0006169423117905509, n_hidden=3, n_neurons=22; total ti
me=  18.5s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 3.3637 - val_los
s: 1.6579
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.1658 - val_los
s: 0.9539
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8408 - val_los
s: 0.7910
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7131 - val_los
s: 0.7087
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6442 - val_los
s: 0.6612
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6018 - val_los
s: 0.6289
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5724 - val_los
s: 0.6033
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5496 - val_los
s: 0.5825
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5310 - val_los
s: 0.5649
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5162 - val_los
s: 0.5498
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5039 - val_los
s: 0.5371
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4933 - val_los
s: 0.5265
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4844 - val_los
s: 0.5162
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4763 - val_los
s: 0.5074
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4694 - val_los
s: 0.4999
```

```
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4631 - val_los
s: 0.4929
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4576 - val_los
s: 0.4869
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4526 - val_los
s: 0.4816
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4480 - val_los
s: 0.4762
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4439 - val_los
s: 0.4713
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4403 - val_los
s: 0.4671
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4368 - val_los
s: 0.4636
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4337 - val_los
s: 0.4600
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4309 - val_los
s: 0.4568
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4282 - val_los
s: 0.4539
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4258 - val_los
s: 0.4517
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4236 - val_los
s: 0.4492
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4215 - val_los
s: 0.4465
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4196 - val_los
s: 0.4443
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4177 - val_los
s: 0.4424
138/138 [==============================] - 0s 1ms/step - loss: 0.4410
[CV] END learning_rate=0.0006169423117905509, n_hidden=3, n_neurons=22; total ti
me=  18.7s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 2.3105 - val_los
s: 1.2355
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.0015 - val_los
s: 0.8953
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7661 - val_los
s: 0.7409
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6541 - val_los
s: 0.6669
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5965 - val_los
s: 0.6243
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5630 - val_los
```

```
s: 0.5965
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5402 - val_los
s: 0.5745
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5233 - val_los
s: 0.5587
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5108 - val_los
s: 0.5443
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5008 - val_los
s: 0.5331
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4923 - val_los
s: 0.5232
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4850 - val_los
s: 0.5164
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4792 - val_los
s: 0.5080
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4736 - val_los
s: 0.5028
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4694 - val_los
s: 0.4977
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4654 - val_los
s: 0.4924
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4617 - val_los
s: 0.4876
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4586 - val_los
s: 0.4840
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4558 - val_los
s: 0.4804
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4528 - val_los
s: 0.4773
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4505 - val_los
s: 0.4741
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4481 - val_los
s: 0.4731
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4463 - val_los
s: 0.4698
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4436 - val_los
s: 0.4698
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4420 - val_los
s: 0.4651
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4400 - val_los
s: 0.4620
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4382 - val_los
s: 0.4610
Epoch 28/30
```

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276/276 [==============================] - 1s 2ms/step - loss: 0.4366 - val_los
s: 0.4577
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4348 - val_los
s: 0.4557
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4332 - val_los
s: 0.4542
138/138 [==============================] - 0s 2ms/step - loss: 0.4400
[CV] END learning_rate=0.0006169423117905509, n_hidden=3, n_neurons=22; total ti
me=  21.2s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 3.0438 - val_los
s: 1.7168
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.3844 - val_los
s: 1.1910
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 1.0973 - val_los
s: 1.0042
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.9365 - val_los
s: 0.8797
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8288 - val_los
s: 0.8015
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7587 - val_los
s: 0.7494
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7097 - val_los
s: 0.7107
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6731 - val_los
s: 0.6794
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6433 - val_los
s: 0.6529
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6179 - val_los
s: 0.6301
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5962 - val_los
s: 0.6091
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5771 - val_los
s: 0.5909
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5604 - val_los
s: 0.5749
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5455 - val_los
s: 0.5597
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5324 - val_los
s: 0.5471
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5212 - val_los
s: 0.5358
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5110 - val_los
s: 0.5266
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5023 - val_los
s: 0.5170
```

```
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4943 - val_los
s: 0.5088
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4875 - val_los
s: 0.5018
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4816 - val_los
s: 0.4954
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4765 - val_los
s: 0.4902
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4720 - val_los
s: 0.4850
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4679 - val_los
s: 0.4807
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4642 - val_los
s: 0.4769
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4606 - val_los
s: 0.4727
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4574 - val_los
s: 0.4694
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4545 - val_los
s: 0.4667
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4515 - val_los
s: 0.4634
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4490 - val_los
s: 0.4608
138/138 [==============================] - 0s 1ms/step - loss: 0.4288
[CV] END learning_rate=0.0005862763480424351, n_hidden=3, n_neurons=15; total ti
me=  21.3s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 2.7586 - val_los
s: 1.3674
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.0469 - val_los
s: 0.9304
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7819 - val_los
s: 0.7740
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6791 - val_los
s: 0.7083
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6330 - val_los
s: 0.6706
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6037 - val_los
s: 0.6434
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5826 - val_los
s: 0.6228
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5662 - val_los
s: 0.6058
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5521 - val_los
```

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s: 0.5914
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5404 - val_los
s: 0.5799
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5303 - val_los
s: 0.5692
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5212 - val_los
s: 0.5602
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5134 - val_los
s: 0.5515
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5061 - val_los
s: 0.5434
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4993 - val_los
s: 0.5365
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4931 - val_los
s: 0.5302
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4878 - val_los
s: 0.5243
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4825 - val_los
s: 0.5183
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4775 - val_los
s: 0.5132
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4731 - val_los
s: 0.5083
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4688 - val_los
s: 0.5037
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4650 - val_los
s: 0.4992
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4612 - val_los
s: 0.4951
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4576 - val_los
s: 0.4914
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4543 - val_los
s: 0.4879
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4512 - val_los
s: 0.4842
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4480 - val_los
s: 0.4809
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4452 - val_los
s: 0.4777
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4425 - val_los
s: 0.4747
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4398 - val_los
s: 0.4718
138/138 [==============================] - 0s 1ms/step - loss: 0.4796
```

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[CV] END learning_rate=0.0005862763480424351, n_hidden=3, n_neurons=15; total ti
me=  18.6s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 4.4290 - val_los
s: 2.2019
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.4970 - val_los
s: 1.1573
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.9717 - val_los
s: 0.8670
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7593 - val_los
s: 0.7213
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6535 - val_los
s: 0.6540
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6027 - val_los
s: 0.6210
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5754 - val_los
s: 0.6003
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5580 - val_los
s: 0.5851
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5447 - val_los
s: 0.5716
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5337 - val_los
s: 0.5623
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5250 - val_los
s: 0.5526
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5177 - val_los
s: 0.5447
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5113 - val_los
s: 0.5378
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5058 - val_los
s: 0.5326
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5010 - val_los
s: 0.5271
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4965 - val_los
s: 0.5221
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4925 - val_los
s: 0.5173
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4886 - val_los
s: 0.5135
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4852 - val_los
s: 0.5093
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4818 - val_los
s: 0.5047
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4788 - val_los
s: 0.5022
```

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Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4762 - val_los
s: 0.4986
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4734 - val_los
s: 0.4956
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4711 - val_los
s: 0.4929
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4688 - val_los
s: 0.4909
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4666 - val_los
s: 0.4879
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4644 - val_los
s: 0.4864
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4624 - val_los
s: 0.4843
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4604 - val_los
s: 0.4823
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4583 - val_los
s: 0.4789
138/138 [==============================] - 0s 1ms/step - loss: 0.4517
[CV] END learning_rate=0.0005862763480424351, n_hidden=3, n_neurons=15; total ti
me=  18.8s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 3.3856 - val_los
s: 1.3361
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.9570 - val_los
s: 0.7660
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6907 - val_los
s: 0.6738
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6254 - val_los
s: 0.6327
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5903 - val_los
s: 0.6047
Epoch 6/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5658 - val_los
s: 0.5848
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5485 - val_los
s: 0.5695
Epoch 8/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5357 - val_los
s: 0.5573
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5262 - val_los
s: 0.5480
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5188 - val_los
s: 0.5412
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5133 - val_los
s: 0.5345
Epoch 12/30
276/276 [==============================] - 0s 2ms/step - loss: 0.5089 - val_los
```

```
s: 0.5306
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5058 - val_los
s: 0.5260
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5029 - val_los
s: 0.5230
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5009 - val_los
s: 0.5210
Epoch 16/30
276/276 [==============================] - 0s 2ms/step - loss: 0.4989 - val_los
s: 0.5179
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4975 - val_los
s: 0.5162
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4962 - val_los
s: 0.5149
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4954 - val_los
s: 0.5127
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4942 - val_los
s: 0.5111
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4935 - val_los
s: 0.5106
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4923 - val_los
s: 0.5090
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4918 - val_los
s: 0.5079
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4914 - val_los
s: 0.5066
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4908 - val_los
s: 0.5057
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4902 - val_los
s: 0.5051
Epoch 27/30
276/276 [==============================] - 0s 2ms/step - loss: 0.4896 - val_los
s: 0.5046
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4892 - val_los
s: 0.5037
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4891 - val_los
s: 0.5039
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4886 - val_los
s: 0.5023
138/138 [==============================] - 0s 1ms/step - loss: 0.4713
[CV] END learning_rate=0.0017492192506017832, n_hidden=0, n_neurons=89; total ti
me=  16.9s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 2.8490 - val_los
s: 1.2149
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8316 - val_los
s: 0.6881
Epoch 3/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.5986 - val_los
s: 0.6045
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5515 - val_los
s: 0.5768
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5324 - val_los
s: 0.5610
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5205 - val_los
s: 0.5493
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5117 - val_los
s: 0.5405
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5050 - val_los
s: 0.5341
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5001 - val_los
s: 0.5269
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4961 - val_los
s: 0.5222
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4927 - val_los
s: 0.5186
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4901 - val_los
s: 0.5147
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4877 - val_los
s: 0.5119
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4859 - val_los
s: 0.5091
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4842 - val_los
s: 0.5072
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4825 - val_los
s: 0.5065
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4816 - val_los
s: 0.5038
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4805 - val_los
s: 0.5029
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4798 - val_los
s: 0.5013
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4789 - val_los
s: 0.5001
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4782 - val_los
s: 0.4991
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4775 - val_los
s: 0.4984
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4767 - val_los
s: 0.4979
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4762 - val_los
s: 0.4971
```

```
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4759 - val_los
s: 0.4966
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4751 - val_los
s: 0.4972
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4747 - val_los
s: 0.4958
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4746 - val_los
s: 0.4952
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4742 - val_los
s: 0.4953
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4740 - val_los
s: 0.4944
138/138 [==============================] - 0s 1ms/step - loss: 0.4929
[CV] END learning_rate=0.0017492192506017832, n_hidden=0, n_neurons=89; total ti
me=  17.6s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 3.3406 - val_los
s: 1.2724
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8712 - val_los
s: 0.6811
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6149 - val_los
s: 0.5982
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5648 - val_los
s: 0.5708
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5423 - val_los
s: 0.5540
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5275 - val_los
s: 0.5418
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5165 - val_los
s: 0.5320
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5082 - val_los
s: 0.5244
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5018 - val_los
s: 0.5182
Epoch 10/30
276/276 [==============================] - 0s 2ms/step - loss: 0.4967 - val_los
s: 0.5133
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4930 - val_los
s: 0.5095
Epoch 12/30
276/276 [==============================] - 0s 2ms/step - loss: 0.4898 - val_los
s: 0.5065
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4874 - val_los
s: 0.5041
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4853 - val_los
s: 0.5016
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4838 - val_los
```

```
s: 0.4999
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4824 - val_los
s: 0.4986
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4813 - val_los
s: 0.4976
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4804 - val_los
s: 0.4961
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4797 - val_los
s: 0.4952
Epoch 20/30
276/276 [==============================] - 0s 2ms/step - loss: 0.4791 - val_los
s: 0.4945
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4785 - val_los
s: 0.4938
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4780 - val_los
s: 0.4928
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4777 - val_los
s: 0.4926
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4773 - val_los
s: 0.4925
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4771 - val_los
s: 0.4917
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4768 - val_los
s: 0.4915
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4765 - val_los
s: 0.4911
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4763 - val_los
s: 0.4909
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4761 - val_los
s: 0.4906
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4760 - val_los
s: 0.4907
138/138 [==============================] - 0s 1ms/step - loss: 0.4775
[CV] END learning_rate=0.0017492192506017832, n_hidden=0, n_neurons=89; total ti
me=  21.5s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 3.4388 - val_los
s: 1.7579
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.3077 - val_los
s: 0.9995
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8612 - val_los
s: 0.7656
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7063 - val_los
s: 0.6797
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6389 - val_los
s: 0.6346
Epoch 6/30
```

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276/276 [==============================] - 1s 2ms/step - loss: 0.6012 - val_los
s: 0.6052
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5759 - val_los
s: 0.5836
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5566 - val_los
s: 0.5662
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5410 - val_los
s: 0.5522
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5285 - val_los
s: 0.5394
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5178 - val_los
s: 0.5291
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5088 - val_los
s: 0.5201
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5013 - val_los
s: 0.5124
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4947 - val_los
s: 0.5060
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4893 - val_los
s: 0.5001
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4844 - val_los
s: 0.4950
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4802 - val_los
s: 0.4909
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4765 - val_los
s: 0.4869
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4731 - val_los
s: 0.4830
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4701 - val_los
s: 0.4804
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4675 - val_los
s: 0.4774
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4648 - val_los
s: 0.4751
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4628 - val_los
s: 0.4734
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4608 - val_los
s: 0.4707
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4589 - val_los
s: 0.4687
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4569 - val_los
s: 0.4672
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4555 - val_los
s: 0.4654
```

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Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4538 - val_los
s: 0.4638
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4525 - val_los
s: 0.4620
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4510 - val_los
s: 0.4605
138/138 [==============================] - 0s 1ms/step - loss: 0.4297
[CV] END learning_rate=0.0006243610734880342, n_hidden=1, n_neurons=27; total ti
me=  18.7s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 3.0039 - val_los
s: 1.7235
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 1.3358 - val_los
s: 1.1304
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.9789 - val_los
s: 0.9301
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.8300 - val_los
s: 0.8309
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7490 - val_los
s: 0.7723
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6979 - val_los
s: 0.7319
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6623 - val_los
s: 0.7018
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6349 - val_los
s: 0.6762
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6124 - val_los
s: 0.6550
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5938 - val_los
s: 0.6369
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5781 - val_los
s: 0.6214
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5648 - val_los
s: 0.6077
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5531 - val_los
s: 0.5954
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5425 - val_los
s: 0.5843
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5331 - val_los
s: 0.5741
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5245 - val_los
s: 0.5645
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5167 - val_los
s: 0.5563
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5094 - val_los
```

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s: 0.5487
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5029 - val_los
s: 0.5411
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4966 - val_los
s: 0.5342
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4907 - val_los
s: 0.5280
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4855 - val_los
s: 0.5222
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4807 - val_los
s: 0.5167
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4762 - val_los
s: 0.5116
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4721 - val_los
s: 0.5069
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4684 - val_los
s: 0.5024
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4649 - val_los
s: 0.4982
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4616 - val_los
s: 0.4943
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4586 - val_los
s: 0.4908
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4558 - val_los
s: 0.4873
138/138 [==============================] - 0s 2ms/step - loss: 0.4839
[CV] END learning_rate=0.0006243610734880342, n_hidden=1, n_neurons=27; total ti
me=  21.1s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 2.3426 - val_los
s: 1.2698
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.9928 - val_los
s: 0.8815
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7949 - val_los
s: 0.7917
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.7243 - val_los
s: 0.7405
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6791 - val_los
s: 0.7018
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6449 - val_los
s: 0.6706
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6178 - val_los
s: 0.6449
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5957 - val_los
s: 0.6230
Epoch 9/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.5769 - val_los
s: 0.6047
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5611 - val_los
s: 0.5889
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5475 - val_los
s: 0.5750
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5357 - val_los
s: 0.5632
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5255 - val_los
s: 0.5528
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5166 - val_los
s: 0.5438
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5090 - val_los
s: 0.5359
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5023 - val_los
s: 0.5289
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4963 - val_los
s: 0.5229
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4912 - val_los
s: 0.5173
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4864 - val_los
s: 0.5123
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4823 - val_los
s: 0.5078
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4783 - val_los
s: 0.5036
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4748 - val_los
s: 0.4996
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4716 - val_los
s: 0.4963
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4686 - val_los
s: 0.4932
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4659 - val_los
s: 0.4901
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4633 - val_los
s: 0.4876
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4609 - val_los
s: 0.4849
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4587 - val_los
s: 0.4826
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4565 - val_los
s: 0.4805
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4545 - val_los
s: 0.4778
```

```
138/138 [==============================] - 0s 1ms/step - loss: 0.4560
[CV] END learning_rate=0.0006243610734880342, n_hidden=1, n_neurons=27; total ti
me=  18.8s
Epoch 1/30
276/276 [==============================] - 1s 2ms/step - loss: 1.2081 - val_los
s: 0.6821
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6128 - val_los
s: 0.5870
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5456 - val_los
s: 0.5466
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5070 - val_los
s: 0.5123
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4870 - val_los
s: 0.4984
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4748 - val_los
s: 0.4794
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4644 - val_los
s: 0.4696
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4572 - val_los
s: 0.4617
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4513 - val_los
s: 0.4595
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4469 - val_los
s: 0.4551
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4425 - val_los
s: 0.4479
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4394 - val_los
s: 0.4451
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4365 - val_los
s: 0.4395
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4336 - val_los
s: 0.4416
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4315 - val_los
s: 0.4376
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4298 - val_los
s: 0.4325
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4279 - val_los
s: 0.4300
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4257 - val_los
s: 0.4304
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4243 - val_los
s: 0.4267
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4232 - val_los
s: 0.4273
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4220 - val_los
```

```
s: 0.4229
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4207 - val_los
s: 0.4218
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4193 - val_los
s: 0.4229
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4167 - val_los
s: 0.4291
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4170 - val_los
s: 0.4180
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4148 - val_los
s: 0.4200
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4141 - val_los
s: 0.4146
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4125 - val_los
s: 0.4206
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4127 - val_los
s: 0.4242
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4105 - val_los
s: 0.4122
138/138 [==============================] - 0s 2ms/step - loss: 0.4011
[CV] END learning_rate=0.003652084074475273, n_hidden=3, n_neurons=4; total time
=  19.5s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 1.3376 - val_los
s: 0.7913
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.6703 - val_los
s: 0.6529
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5834 - val_los
s: 0.5946
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5348 - val_los
s: 0.5537
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5042 - val_los
s: 0.5347
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4861 - val_los
s: 0.5126
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4741 - val_los
s: 0.5010
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4655 - val_los
s: 0.4905
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4593 - val_los
s: 0.4838
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4537 - val_los
s: 0.4783
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4486 - val_los
s: 0.4726
Epoch 12/30
```

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276/276 [==============================] - 1s 2ms/step - loss: 0.4446 - val_los
s: 0.4693
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4402 - val_los
s: 0.4635
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4373 - val_los
s: 0.4590
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4340 - val_los
s: 0.4550
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4306 - val_los
s: 0.4518
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4285 - val_los
s: 0.4480
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4258 - val_los
s: 0.4480
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4234 - val_los
s: 0.4427
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4215 - val_los
s: 0.4429
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4196 - val_los
s: 0.4400
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4182 - val_los
s: 0.4360
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4166 - val_los
s: 0.4438
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4150 - val_los
s: 0.4348
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4136 - val_los
s: 0.4413
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4126 - val_los
s: 0.4298
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4112 - val_los
s: 0.4281
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4091 - val_los
s: 0.4265
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4082 - val_los
s: 0.4266
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4068 - val_los
s: 0.4261
138/138 [==============================] - 0s 1ms/step - loss: 0.4322
[CV] END learning_rate=0.003652084074475273, n_hidden=3, n_neurons=4; total time
=  19.4s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 1.3064 - val_los
s: 0.6799
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5723 - val_los
s: 0.5584
```

```
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5098 - val_los
s: 0.5231
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4884 - val_los
s: 0.5104
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4779 - val_los
s: 0.4974
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4713 - val_los
s: 0.4938
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4667 - val_los
s: 0.4864
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4635 - val_los
s: 0.4836
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4607 - val_los
s: 0.4797
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4583 - val_los
s: 0.4805
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4561 - val_los
s: 0.4788
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4541 - val_los
s: 0.4722
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4522 - val_los
s: 0.4736
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4508 - val_los
s: 0.4666
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4496 - val_los
s: 0.4672
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4479 - val_los
s: 0.4659
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4462 - val_los
s: 0.4674
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4455 - val_los
s: 0.4634
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4444 - val_los
s: 0.4817
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4432 - val_los
s: 0.4618
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4418 - val_los
s: 0.4564
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4407 - val_los
s: 0.4563
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4397 - val_los
s: 0.4578
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4389 - val_los
```

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s: 0.4554
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4375 - val_los
s: 0.4550
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4364 - val_los
s: 0.4534
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4352 - val_los
s: 0.4530
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4332 - val_los
s: 0.4497
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4326 - val_los
s: 0.4492
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4316 - val_los
s: 0.4478
138/138 [==============================] - 0s 2ms/step - loss: 0.4320
[CV] END learning_rate=0.003652084074475273, n_hidden=3, n_neurons=4; total time
=  19.9s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.5404 - val_los
s: 0.4224
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4064 - val_los
s: 0.3906
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3812 - val_los
s: 0.3741
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3737 - val_los
s: 0.4230
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3644 - val_los
s: 0.3781
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3585 - val_los
s: 0.6053
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3538 - val_los
s: 0.3667
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3485 - val_los
s: 0.3764
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3405 - val_los
s: 0.3781
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3370 - val_los
s: 0.3371
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3359 - val_los
s: 0.3392
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3316 - val_los
s: 0.3703
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3299 - val_los
s: 0.6352
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3283 - val_los
s: 0.3452
Epoch 15/30
```

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276/276 [==============================] - 1s 2ms/step - loss: 0.3214 - val_los
s: 0.3470
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3221 - val_los
s: 0.3438
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3166 - val_los
s: 0.3355
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3153 - val_los
s: 0.4272
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3137 - val_los
s: 0.4802
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3107 - val_los
s: 0.3628
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3086 - val_los
s: 0.3113
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3050 - val_los
s: 0.3409
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3055 - val_los
s: 0.3879
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3034 - val_los
s: 0.3409
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2997 - val_los
s: 0.3966
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3043 - val_los
s: 0.3214
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2981 - val_los
s: 0.3211
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2991 - val_los
s: 0.3877
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2967 - val_los
s: 0.3077
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2947 - val_los
s: 0.3146
138/138 [==============================] - 0s 2ms/step - loss: 0.3178
[CV] END learning_rate=0.026493843442839206, n_hidden=2, n_neurons=42; total tim
e=  19.9s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.6417 - val_los
s: 0.5203
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4050 - val_los
s: 0.4940
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3814 - val_los
s: 0.4404
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3662 - val_los
s: 0.4514
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3572 - val_los
s: 0.3747
```

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Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3506 - val_los
s: 0.3522
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3439 - val_los
s: 0.3755
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3402 - val_los
s: 0.3583
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3352 - val_los
s: 0.3846
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3312 - val_los
s: 0.3477
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3267 - val_los
s: 0.3451
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3233 - val_los
s: 0.3362
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3239 - val_los
s: 0.3355
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3169 - val_los
s: 0.4134
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3168 - val_los
s: 0.3406
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3115 - val_los
s: 0.3569
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3099 - val_los
s: 0.3304
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3051 - val_los
s: 0.3393
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3096 - val_los
s: 0.3433
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3028 - val_los
s: 0.3301
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3018 - val_los
s: 0.3276
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3008 - val_los
s: 0.3493
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2965 - val_los
s: 0.3353
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2978 - val_los
s: 0.3203
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2936 - val_los
s: 0.3538
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2914 - val_los
s: 0.3120
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2929 - val_los
```

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s: 0.3165
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2879 - val_los
s: 0.3440
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2884 - val_los
s: 0.4070
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2888 - val_los
s: 0.3445
138/138 [==============================] - 0s 2ms/step - loss: 0.3590
[CV] END learning_rate=0.026493843442839206, n_hidden=2, n_neurons=42; total tim
e=  20.2s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.5633 - val_los
s: 0.4435
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4059 - val_los
s: 0.9387
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3891 - val_los
s: 0.4654
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3718 - val_los
s: 0.4030
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3613 - val_los
s: 0.3610
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3514 - val_los
s: 0.4274
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3462 - val_los
s: 0.3467
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3423 - val_los
s: 0.3905
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3370 - val_los
s: 0.3487
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3332 - val_los
s: 0.3518
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3267 - val_los
s: 0.4041
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3242 - val_los
s: 0.3496
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3205 - val_los
s: 0.3292
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3161 - val_los
s: 0.3321
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3132 - val_los
s: 0.3466
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3125 - val_los
s: 0.3291
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3103 - val_los
s: 0.3294
Epoch 18/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.3043 - val_los
s: 0.3199
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3026 - val_los
s: 0.3481
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3034 - val_los
s: 0.3207
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2987 - val_los
s: 0.4965
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2991 - val_los
s: 0.3438
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2974 - val_los
s: 0.3805
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2931 - val_los
s: 0.3539
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2938 - val_los
s: 0.3264
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2905 - val_los
s: 0.3977
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2928 - val_los
s: 0.3188
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2872 - val_los
s: 0.3598
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2867 - val_los
s: 0.3889
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.2889 - val_los
s: 0.3134
138/138 [==============================] - 0s 2ms/step - loss: 0.3098
[CV] END learning_rate=0.026493843442839206, n_hidden=2, n_neurons=42; total tim
e=  19.8s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 1.0708 - val_los
s: 0.6121
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5403 - val_los
s: 0.5205
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4808 - val_los
s: 0.4767
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4507 - val_los
s: 0.4515
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4310 - val_los
s: 0.4376
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4167 - val_los
s: 0.4215
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4051 - val_los
s: 0.4117
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3975 - val_los
s: 0.4008
```

```
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3907 - val_los
s: 0.3994
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3848 - val_los
s: 0.3928
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3791 - val_los
s: 0.3853
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3750 - val_los
s: 0.3801
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3703 - val_los
s: 0.3868
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3664 - val_los
s: 0.3720
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3633 - val_los
s: 0.3666
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3600 - val_los
s: 0.3653
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3572 - val_los
s: 0.3643
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3541 - val_los
s: 0.3584
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3523 - val_los
s: 0.3583
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3496 - val_los
s: 0.3539
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3469 - val_los
s: 0.3528
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3448 - val_los
s: 0.3549
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3437 - val_los
s: 0.3513
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3419 - val_los
s: 0.3491
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3398 - val_los
s: 0.3518
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3380 - val_los
s: 0.3464
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3366 - val_los
s: 0.3487
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3364 - val_los
s: 0.3468
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3339 - val_los
s: 0.3491
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3332 - val_los
```

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s: 0.3411
138/138 [==============================] - 0s 2ms/step - loss: 0.3395
[CV] END learning_rate=0.003866289668516478, n_hidden=2, n_neurons=50; total tim
e=  20.2s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 1.0011 - val_los
s: 0.6714
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.5502 - val_los
s: 0.5622
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4770 - val_los
s: 0.4984
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4423 - val_los
s: 0.4636
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4217 - val_los
s: 0.4450
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4081 - val_los
s: 0.4288
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3981 - val_los
s: 0.4217
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3896 - val_los
s: 0.4125
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3841 - val_los
s: 0.4068
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3784 - val_los
s: 0.3997
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3727 - val_los
s: 0.4025
Epoch 12/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3687 - val_los
s: 0.3883
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3653 - val_los
s: 0.3839
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3617 - val_los
s: 0.3821
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3588 - val_los
s: 0.3815
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3558 - val_los
s: 0.3752
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3524 - val_los
s: 0.3743
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3495 - val_los
s: 0.3694
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3479 - val_los
s: 0.3714
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3459 - val_los
s: 0.3657
Epoch 21/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.3439 - val_los
s: 0.3660
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3422 - val_los
s: 0.3633
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3402 - val_los
s: 0.3797
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3388 - val_los
s: 0.3599
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3374 - val_los
s: 0.3628
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3362 - val_los
s: 0.3563
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3348 - val_los
s: 0.3635
Epoch 28/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3331 - val_los
s: 0.3541
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3311 - val_los
s: 0.3536
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3307 - val_los
s: 0.3538
138/138 [==============================] - 0s 2ms/step - loss: 0.3592
[CV] END learning_rate=0.003866289668516478, n_hidden=2, n_neurons=50; total tim
e=  21.2s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 1.0246 - val_los
s: 0.5869
Epoch 2/30
276/276 [==============================] - 1s 3ms/step - loss: 0.5064 - val_los
s: 0.5033
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4612 - val_los
s: 0.4744
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4382 - val_los
s: 0.4470
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4235 - val_los
s: 0.4322
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4123 - val_los
s: 0.4266
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4041 - val_los
s: 0.4138
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3970 - val_los
s: 0.4127
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3923 - val_los
s: 0.3993
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3864 - val_los
s: 0.3963
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3823 - val_los
s: 0.3951
```

```
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3787 - val_los
s: 0.3888
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3755 - val_los
s: 0.3860
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3725 - val_los
s: 0.3818
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3695 - val_los
s: 0.3783
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3662 - val_los
s: 0.3818
Epoch 17/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3639 - val_los
s: 0.3734
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3613 - val_los
s: 0.3756
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3590 - val_los
s: 0.3717
Epoch 20/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3574 - val_los
s: 0.3679
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3553 - val_los
s: 0.3713
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3539 - val_los
s: 0.3665
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3524 - val_los
s: 0.3691
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3509 - val_los
s: 0.3613
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3489 - val_los
s: 0.3604
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3476 - val_los
s: 0.3594
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3461 - val_los
s: 0.3707
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3451 - val_los
s: 0.3624
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3437 - val_los
s: 0.3545
Epoch 30/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3426 - val_los
s: 0.3548
138/138 [==============================] - 0s 2ms/step - loss: 0.3450
[CV] END learning_rate=0.003866289668516478, n_hidden=2, n_neurons=50; total tim
e=  20.9s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.8779 - val_los
s: 0.5676
Epoch 2/30
276/276 [==============================] - 1s 3ms/step - loss: 0.4725 - val_los
```

```
s: 0.4841
Epoch 3/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4293 - val_los
s: 0.4305
Epoch 4/30
276/276 [==============================] - 1s 3ms/step - loss: 0.4091 - val_los
s: 0.4133
Epoch 5/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3945 - val_los
s: 0.3966
Epoch 6/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3842 - val_los
s: 0.3912
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3758 - val_los
s: 0.3832
Epoch 8/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3691 - val_los
s: 0.3819
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3643 - val_los
s: 0.3711
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3588 - val_los
s: 0.3687
Epoch 11/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3545 - val_los
s: 0.3695
Epoch 12/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3501 - val_los
s: 0.3709
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3473 - val_los
s: 0.3531
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3416 - val_los
s: 0.3686
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3411 - val_los
s: 0.3591
Epoch 16/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3360 - val_los
s: 0.3562
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3341 - val_los
s: 0.3467
Epoch 18/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3315 - val_los
s: 0.3452
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3304 - val_los
s: 0.3409
Epoch 20/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3265 - val_los
s: 0.3402
Epoch 21/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3248 - val_los
s: 0.3424
Epoch 22/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3224 - val_los
s: 0.3406
Epoch 23/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3210 - val_los
s: 0.3516
Epoch 24/30
```

```
276/276 [==============================] - 1s 2ms/step - loss: 0.3187 - val_los
s: 0.3383
Epoch 25/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3161 - val_los
s: 0.3440
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3151 - val_los
s: 0.3344
Epoch 27/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3120 - val_los
s: 0.3373
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3120 - val_los
s: 0.3293
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3103 - val_los
s: 0.3339
Epoch 30/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3081 - val_los
s: 0.3554
138/138 [==============================] - 0s 2ms/step - loss: 0.3564
[CV] END learning_rate=0.005265222470937165, n_hidden=3, n_neurons=73; total tim
e=  21.8s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.8470 - val_los
s: 0.5337
Epoch 2/30
276/276 [==============================] - 1s 2ms/step - loss: 0.4590 - val_los
s: 0.4653
Epoch 3/30
276/276 [==============================] - 1s 3ms/step - loss: 0.4186 - val_los
s: 0.4407
Epoch 4/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3980 - val_los
s: 0.4118
Epoch 5/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3838 - val_los
s: 0.4056
Epoch 6/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3739 - val_los
s: 0.3983
Epoch 7/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3664 - val_los
s: 0.3877
Epoch 8/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3589 - val_los
s: 0.3778
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3536 - val_los
s: 0.3708
Epoch 10/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3480 - val_los
s: 0.3747
Epoch 11/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3443 - val_los
s: 0.3686
Epoch 12/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3410 - val_los
s: 0.3554
Epoch 13/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3368 - val_los
s: 0.3507
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3338 - val_los
s: 0.3494
```

```
Epoch 15/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3295 - val_los
s: 0.3478
Epoch 16/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3270 - val_los
s: 0.3469
Epoch 17/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3249 - val_los
s: 0.3606
Epoch 18/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3243 - val_los
s: 0.3451
Epoch 19/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3210 - val_los
s: 0.3438
Epoch 20/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3197 - val_los
s: 0.3379
Epoch 21/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3168 - val_los
s: 0.3404
Epoch 22/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3153 - val_los
s: 0.3390
Epoch 23/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3132 - val_los
s: 0.3597
Epoch 24/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3119 - val_los
s: 0.3726
Epoch 25/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3099 - val_los
s: 0.3528
Epoch 26/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3068 - val_los
s: 0.3362
Epoch 27/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3061 - val_los
s: 0.3359
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3036 - val_los
s: 0.4076
Epoch 29/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3040 - val_los
s: 0.3353
Epoch 30/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3007 - val_los
s: 0.3414
138/138 [==============================] - 0s 2ms/step - loss: 0.3455
[CV] END learning_rate=0.005265222470937165, n_hidden=3, n_neurons=73; total tim
e=  21.8s
Epoch 1/30
276/276 [==============================] - 1s 3ms/step - loss: 0.7494 - val_los
s: 0.5337
Epoch 2/30
276/276 [==============================] - 1s 3ms/step - loss: 0.4650 - val_los
s: 0.4617
Epoch 3/30
276/276 [==============================] - 1s 3ms/step - loss: 0.4252 - val_los
s: 0.4276
Epoch 4/30
276/276 [==============================] - 1s 3ms/step - loss: 0.4052 - val_los
s: 0.4149
Epoch 5/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3925 - val_los
```

```
s: 0.3984
Epoch 6/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3833 - val_los
s: 0.3907
Epoch 7/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3751 - val_los
s: 0.3857
Epoch 8/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3706 - val_los
s: 0.3816
Epoch 9/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3646 - val_los
s: 0.3769
Epoch 10/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3616 - val_los
s: 0.3691
Epoch 11/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3564 - val_los
s: 0.3623
Epoch 12/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3525 - val_los
s: 0.3661
Epoch 13/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3502 - val_los
s: 0.3621
Epoch 14/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3467 - val_los
s: 0.3616
Epoch 15/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3434 - val_los
s: 0.3531
Epoch 16/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3414 - val_los
s: 0.3568
Epoch 17/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3395 - val_los
s: 0.3494
Epoch 18/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3373 - val_los
s: 0.3634
Epoch 19/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3350 - val_los
s: 0.4087
Epoch 20/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3342 - val_los
s: 0.3648
Epoch 21/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3305 - val_los
s: 0.3614
Epoch 22/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3289 - val_los
s: 0.3432
Epoch 23/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3266 - val_los
s: 0.3465
Epoch 24/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3254 - val_los
s: 0.3433
Epoch 25/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3244 - val_los
s: 0.3422
Epoch 26/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3210 - val_los
s: 0.3378
Epoch 27/30
```

```
276/276 [==============================] - 1s 3ms/step - loss: 0.3203 - val_los
s: 0.3357
Epoch 28/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3206 - val_los
s: 0.3435
Epoch 29/30
276/276 [==============================] - 1s 2ms/step - loss: 0.3181 - val_los
s: 0.3507
Epoch 30/30
276/276 [==============================] - 1s 3ms/step - loss: 0.3167 - val_los
s: 0.3365
138/138 [==============================] - 0s 2ms/step - loss: 0.3323
[CV] END learning_rate=0.005265222470937165, n_hidden=3, n_neurons=73; total tim
e=  22.6s
Epoch 1/30
413/413 [==============================] - 1s 2ms/step - loss: 0.5431 - val_los
s: 0.4356
Epoch 2/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3941 - val_los
s: 0.6350
Epoch 3/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3749 - val_los
s: 0.3917
Epoch 4/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3601 - val_los
s: 0.3568
Epoch 5/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3544 - val_los
s: 0.3593
Epoch 6/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3444 - val_los
s: 0.3753
Epoch 7/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3398 - val_los
s: 0.3975
Epoch 8/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3358 - val_los
s: 0.3595
Epoch 9/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3279 - val_los
s: 0.3362
Epoch 10/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3242 - val_los
s: 0.3277
Epoch 11/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3200 - val_los
s: 0.3195
Epoch 12/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3179 - val_los
s: 0.3200
Epoch 13/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3150 - val_los
s: 0.3250
Epoch 14/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3108 - val_los
s: 0.3400
Epoch 15/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3074 - val_los
s: 0.3377
Epoch 16/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3050 - val_los
s: 0.3099
Epoch 17/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3031 - val_los
s: 0.3355
```

```
Epoch 18/30
413/413 [==============================] - 1s 2ms/step - loss: 0.3011 - val_los
s: 0.3120
Epoch 19/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2995 - val_los
s: 0.3070
Epoch 20/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2989 - val_los
s: 0.3123
Epoch 21/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2971 - val_los
s: 0.3048
Epoch 22/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2944 - val_los
s: 0.3263
Epoch 23/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2937 - val_los
s: 0.3040
Epoch 24/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2905 - val_los
s: 0.3368
Epoch 25/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2888 - val_los
s: 0.3141
Epoch 26/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2860 - val_los
s: 0.3283
Epoch 27/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2842 - val_los
s: 0.3036
Epoch 28/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2838 - val_los
s: 0.3189
Epoch 29/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2846 - val_los
s: 0.2927
Epoch 30/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2813 - val_los
s: 0.3079
```

Out[22]:
```
RandomizedSearchCV(cv=3,
                   estimator=<keras.wrappers.scikit_learn.KerasRegressor object
at 0x7f99c0ed9ed0>,
                   param_distributions={'learning_rate': [0.018660324072369908,
                                                          0.007644504723105013,
                                                          0.0006520854051037825,
                                                          0.018195520549468946,
                                                          0.007759773905501517,
                                                          0.002416434498857632,
                                                          0.028154254335988504,
                                                          0.01236727955030516,
                                                          0.001430026349082893,
                                                          0.004085515660209816,
                                                          0...
                                                          0.003124650739090614З,
                                                          0.0017485292281239227,
                                                          0.002098148407433953,
                                                          0.0019359456955505697,
                                                          0.0008873943214929799,
                                                          0.0013761511693017496,
                                                          0.004668993857464526,
                                                          0.0009542231770992221,
                                                          0.009483872212692068,
                                                          0.016898283698526653,
...],
                                        'n_hidden': [0, 1, 2, 3],
```

```
                                                'n_neurons': [1, 2, 3, 4, 5, 6, 7, 8, 9,
                                                              10, 11, 12, 13, 14, 15,
                                                              16, 17, 18, 19, 20, 21,
                                                              22, 23, 24, 25, 26, 27,
                                                              28, 29, 30, ...]},
                   verbose=2)
```

In [23]:
```
rnd_search_cv.best_params_
```

Out[23]:
```
{'learning_rate': 0.026493843442839206, 'n_hidden': 2, 'n_neurons': 42}
```

(c) [1 mark]

Plot the learning curves for the best model in (c). Does it look like the model is overfitting?

[Add your solution here]

In [24]:
```
best_model = rnd_search_cv.best_estimator_.model
```

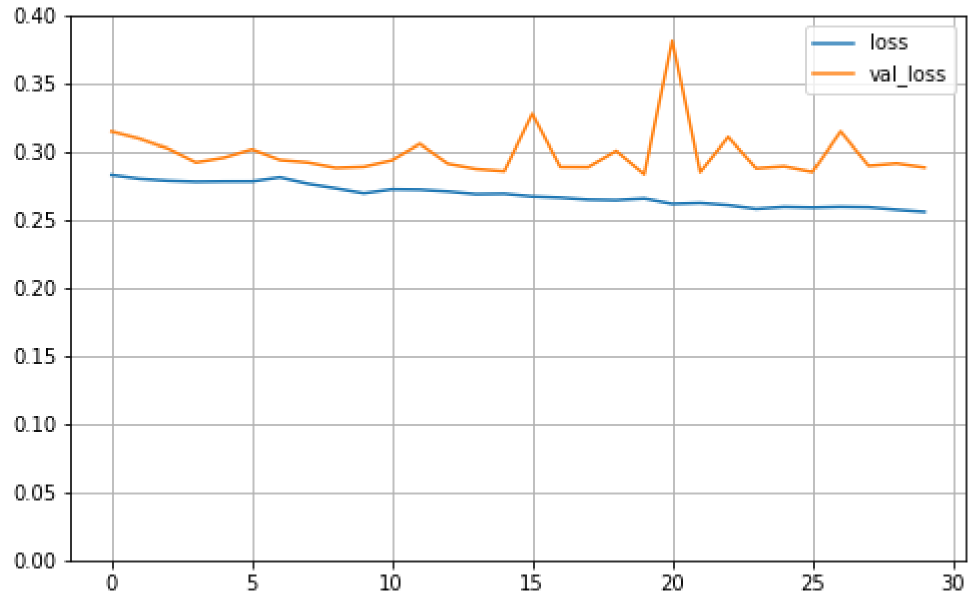
In [25]:
```
res = best_model.fit(X_train, y_train, epochs=30,
                validation_data=(X_valid, y_valid))
```

```
Epoch 1/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2830 - val_los
s: 0.3147
Epoch 2/30
413/413 [==============================] - 1s 3ms/step - loss: 0.2802 - val_los
s: 0.3094
Epoch 3/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2788 - val_los
s: 0.3023
Epoch 4/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2780 - val_los
s: 0.2922
Epoch 5/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2783 - val_los
s: 0.2957
Epoch 6/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2783 - val_los
s: 0.3018
Epoch 7/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2813 - val_los
s: 0.2940
Epoch 8/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2766 - val_los
s: 0.2922
Epoch 9/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2732 - val_los
s: 0.2882
Epoch 10/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2695 - val_los
s: 0.2890
Epoch 11/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2725 - val_los
s: 0.2937
Epoch 12/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2722 - val_los
s: 0.3058
Epoch 13/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2709 - val_los
s: 0.2913
Epoch 14/30
```

```
413/413 [==============================] - 1s 2ms/step - loss: 0.2689 - val_los
s: 0.2874
Epoch 15/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2692 - val_los
s: 0.2857
Epoch 16/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2672 - val_los
s: 0.3277
Epoch 17/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2663 - val_los
s: 0.2889
Epoch 18/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2649 - val_los
s: 0.2888
Epoch 19/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2645 - val_los
s: 0.3006
Epoch 20/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2657 - val_los
s: 0.2835
Epoch 21/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2618 - val_los
s: 0.3814
Epoch 22/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2624 - val_los
s: 0.2851
Epoch 23/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2608 - val_los
s: 0.3107
Epoch 24/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2581 - val_los
s: 0.2878
Epoch 25/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2595 - val_los
s: 0.2894
Epoch 26/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2591 - val_los
s: 0.2852
Epoch 27/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2596 - val_los
s: 0.3147
Epoch 28/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2593 - val_los
s: 0.2897
Epoch 29/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2574 - val_los
s: 0.2915
Epoch 30/30
413/413 [==============================] - 1s 2ms/step - loss: 0.2559 - val_los
s: 0.2885
```

In [26]:

```
import pandas as pd
import matplotlib.pyplot as plt
pd.DataFrame(res.history).plot(figsize=(8, 5))
plt.grid(True)
plt.gca().set_ylim(0, 0.4)
plt.show()
```



Yes, the model looks like overfitting.

2. Binary classification DNN [23 marks]

Consider the Caravan insurance data. The data gives sociodemographic and product ownership data from customers of an insurance company, some of which purchased caravan insurance. You can read ther data description from that website. Download the data as a csv file from Canvas.

The target variable is `Purchase` , which is binary and you should convert it to 1 for `Yes` and 0 for `No` .

(a) [3 marks]

Load, split and preprocess the data. In particular, for the splitting, you will need to create a test set (20% of the full data), a validation set (20% of the remaining data after creating the test set), and a training set, and stratify using the target variable because this is an imbalanced dataset. For both splits, use `random_state=42` . The features `MOSTYPE` and `MOSHOOFD` are categorical so one hot encoding needs to be applied to them. All other features are numerical so a standard scaler needs to be applied to them. Print the training set `X_train` , `y_train` using `print()` .

[Add your solution here]

In [84]:
```
X_raw = pd.read_csv("caravan.csv")
from sklearn.model_selection import StratifiedShuffleSplit

# split raw data set into 20% test set
split = StratifiedShuffleSplit(n_splits=1, test_size=0.2, random_state=42)
for train_index, test_index in split.split(X_raw, X_raw["Purchase"]):
    strat_train_set = X_raw.loc[train_index]
    strat_test_set_1 = X_raw.loc[test_index]
```

```
# split the remaining 20% data after creating the test set into validation set
# and the training set
for valid_index, train_index in split.split(strat_test_set_1,
                                            strat_test_set_1["Purchase"]):
    strat_test_set = strat_test_set_1.iloc[valid_index]
    strat_valid_set = strat_test_set_1.iloc[train_index]
```

In [85]:

```
X_train_new = strat_train_set.drop("Purchase", axis=1)
y_train = (strat_train_set["Purchase"] == "Yes") + 0
```

In [86]:

```
from sklearn.pipeline import Pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.compose import ColumnTransformer
from sklearn.preprocessing import OneHotEncoder

num_pipeline = Pipeline([
        ('std_scaler', StandardScaler()),
    ])
X_train_new_num = X_train_new.drop(["MOSTYPE", "MOSHOOFD"], axis=1)
num_attribs = list(X_train_new_num)
cat_attribs = ["MOSTYPE", "MOSHOOFD"]

full_pipeline = ColumnTransformer([
        ("num", num_pipeline, num_attribs),
        ("cat", OneHotEncoder(), cat_attribs),
    ])
```

In [87]:

```
X_train = full_pipeline.fit_transform(X_train_new)

X_test_new = strat_test_set.drop("Purchase", axis=1)
y_test = (strat_test_set["Purchase"] == "Yes") + 0
X_test = full_pipeline.transform(X_test_new)

X_valid_new = strat_valid_set.drop("Purchase", axis=1)
y_valid = (strat_valid_set["Purchase"] == "Yes") + 0
X_valid = full_pipeline.transform(X_valid_new)
```

In [88]:

```
print(X_train)
```

```
[[-0.27440493 -0.85901763  0.0055585  ...  1.          0.
   0.        ]
 [-0.27440493  0.40694601  0.0055585  ...  1.          0.
   0.        ]
 [-0.27440493  0.40694601  0.0055585  ...  1.          0.
   0.        ]
 ...
 [-0.27440493 -0.85901763  0.0055585  ...  0.          1.
   0.        ]
 [-0.27440493 -0.85901763  2.4708858  ...  1.          0.
   0.        ]
 [-0.27440493  0.40694601  1.23822215 ...  1.          0.
   0.        ]]
```

In [89]:

```
print(y_train)
```

```
198     0
676     0
330     0
1231    0
5545    0
```

```
             ..
5341    0
1486    0
5077    0
1170    0
5819    1
Name: Purchase, Length: 4657, dtype: int64
```

(b) [3 marks]

In the next part (c), you will build and fit a DNN with 5 hidden layers of 200, 200, 100, 100, 50 neurons, respectively. Use the following specifications:

(i) He initialization and the ELU activation function.

(ii) The output layer has 1 neuron with sigmoid activation.

(iii) Compile with `loss="binary_crossentropy"` and `metrics=["AUC"]` (which is ROC AUC).

In this question, explain why the choices (i), (ii), and (iii) are justified.

[Add your solution here]

Since the ELU has negative values, which allows ELU not only has lower computational complecity but also with close zero mean unit activation, like batch nomalization does. The He initialization takes into account the non-linearity of activation functions. So it is suitable for using both ELU and He initialization. Since there is only one target variable, the output layer has one neuron with sigmoid activation. Hence, we should compile with command "loss="binary_crossentropy" and metrics=["AUC"].

(c) [3 marks]

Train the model in (b) for 30 epochs and use exponential scheduling and the NAG optimizer with `momentum=0.9`. Use a learning curve to comment on whether it is overfitting.

At the start of fitting your model, run `reset_session()` given by the following code.

In [33]:
```
import random as python_random

def reset_session(seed=42):
    tf.random.set_seed(seed)
    python_random.seed(seed)
    np.random.seed(seed)
    tf.keras.backend.clear_session()
```

[Add your solution here]

In [34]:
```
def exponential_decay(lr0, s):
    return lambda epoch: lr0 * 0.1**(epoch / s)
lr_scheduler = keras.callbacks.LearningRateScheduler(exponential_decay(lr0=0.01,
```

In [35]:
```
reset_session()
```

```
model = keras.models.Sequential()
model.add(keras.layers.Dense(200, activation="elu", kernel_initializer="he_norma
model.add(keras.layers.Dense(200, activation="elu", kernel_initializer="he_norma
model.add(keras.layers.Dense(100, activation="elu", kernel_initializer="he_norma
model.add(keras.layers.Dense(100, activation="elu", kernel_initializer="he_norma
model.add(keras.layers.Dense(50, activation="elu", kernel_initializer="he_normal
```

In [36]:
```
model.add(keras.layers.Dense(1, activation="sigmoid"))
```

In [37]:
```
optimizer= keras.optimizers.SGD(momentum=0.9, nesterov=True)
model.compile(loss="binary_crossentropy",
              optimizer=optimizer,
              metrics=["AUC"])
```

In [38]:
```
model.evaluate(X_train, y_train)
```

```
146/146 [==============================] - 1s 3ms/step - loss: 0.8543 - auc: 0.5
159
```

Out[38]:
```
[0.8543457388877869, 0.5158929824829102]
```

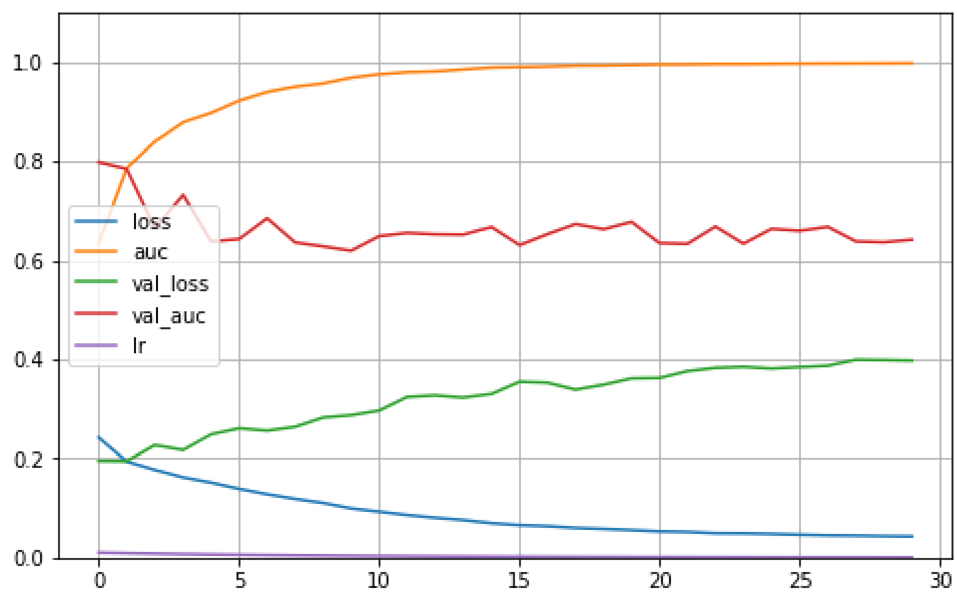
In [39]:
```
model.evaluate(X_valid, y_valid)
```

```
8/8 [==============================] - 0s 3ms/step - loss: 0.8979 - auc: 0.5802
```

Out[39]:
```
[0.8979277014732361, 0.5802348852157593]
```

In [41]:
```
res = model.fit(X_train, y_train, epochs=30,
                callbacks=[lr_scheduler],
                validation_data=(X_valid, y_valid),
                verbose=0)
```

In [42]:
```
import matplotlib.pyplot as plt
pd.DataFrame(res.history).plot(figsize=(8, 5))
plt.grid(True)
plt.gca().set_ylim(0, 1.1)
plt.show()
```



The learning curve shows it is overfitting.

(d) [12 marks]

Fit separate models using the same specification as in (c) but with the following regularization techniques:

(i) batch normalization,

(ii) early stopping based on validation AUC with `patience=10` (look at the documentation and note the `mode` argument).

(iii) ℓ_2 regularization with `l2=0.001`,

(iv) dropout with probability 0.2,

(v) ℓ_2 regularization and early stopping both as above,

(vi) batch normalization and dropout both as above.

At the start of each one of the above models, run `reset_session()`.

The performance measure is validation AUC. State this for the model in (c), and for each of the models here comment on whether it is better than the model in (c).

[Add your solution here]

In [43]:

```
reset_session()
# i
model1 = keras.models.Sequential([
    keras.layers.BatchNormalization(),
    keras.layers.Dense(200, activation="elu", kernel_initializer="he_normal"),
    keras.layers.BatchNormalization(),
    keras.layers.Dense(200, activation="elu", kernel_initializer="he_normal"),
    keras.layers.BatchNormalization(),
    keras.layers.Dense(100, activation="elu", kernel_initializer="he_normal"),
    keras.layers.BatchNormalization(),
    keras.layers.Dense(100, activation="elu", kernel_initializer="he_normal"),
    keras.layers.BatchNormalization(),
    keras.layers.Dense(50, activation="elu", kernel_initializer="he_normal"),
    keras.layers.BatchNormalization(),
    keras.layers.Dense(1, activation="sigmoid")])
```

In [44]:

```
optimizer = keras.optimizers.SGD(momentum=0.9, nesterov=True)
model1.compile(loss="binary_crossentropy",
              optimizer=optimizer,
              metrics=["AUC"])
res_1 = model.fit(X_train, y_train, epochs=30,
                  validation_data=(X_valid, y_valid), verbose=0)
pd.DataFrame(res_1.history).iloc[-11:]
```

Out[44]:

	loss	auc	val_loss	val_auc
19	0.037061	0.997744	0.433728	0.651500
20	0.036454	0.997948	0.435424	0.648402
21	0.036612	0.997720	0.440464	0.646771

	loss	auc	val_loss	val_auc
22	0.035727	0.997982	0.444318	0.648076
23	0.036115	0.997784	0.445730	0.647260
24	0.035835	0.997901	0.442805	0.648565
25	0.035551	0.997922	0.443962	0.644977
26	0.035000	0.997952	0.444988	0.654762
27	0.034991	0.997942	0.455614	0.649543
28	0.034601	0.997943	0.456901	0.647913
29	0.034580	0.998054	0.454539	0.652316

In [45]:

```
# ii
reset_session()
model2 = keras.models.Sequential()
for n_hidden in (200, 200, 100, 100, 50):
    model2.add(keras.layers.Dense(n_hidden, activation="elu",
                                 kernel_initializer="he_normal"))
model2.add(keras.layers.Dense(1, activation="sigmoid"))
optimizer = keras.optimizers.SGD(momentum=0.9, nesterov=True)
model2.compile(loss="binary_crossentropy", optimizer=optimizer,
              metrics=["AUC"])
early_stopping_cb = keras.callbacks.EarlyStopping(monitor='auc',
                                                  mode='max', patience=10)
run_2 = model2.fit(X_train, y_train, epochs=30,
                    validation_data =(X_valid, y_valid),
                    callbacks=[early_stopping_cb],
                    verbose=0)
pd.DataFrame(run_2.history).iloc[-11:]
```

Out[45]:

	loss	auc	val_loss	val_auc
19	0.058405	0.990124	0.387275	0.592629
20	0.057483	0.989366	0.375193	0.615134
21	0.053640	0.991564	0.405090	0.564579
22	0.051944	0.990699	0.397597	0.532290
23	0.053488	0.992204	0.406501	0.636986
24	0.051599	0.993019	0.416124	0.609426
25	0.049535	0.991685	0.369791	0.632583
26	0.046170	0.994740	0.423418	0.595727
27	0.044461	0.993052	0.420730	0.562296
28	0.041400	0.995591	0.455073	0.570776
29	0.043516	0.995098	0.475823	0.604371

In [91]:

```
# iii
from functools import partial
RegularizedDense = partial(keras.layers.Dense,
```

```
                     activation="elu",
                     kernel_initializer="he_normal",
                     kernel_regularizer=keras.regularizers.l2(0.001))
reset_session()
model3 = keras.models.Sequential()
for n_hidden in (200, 200, 100, 100, 50):
    model3.add(RegularizedDense(n_hidden))
model3.add(keras.layers.Dense(1, activation="sigmoid",
                              kernel_regularizer=keras.regularizers.l2(0.001)))
optimizer = keras.optimizers.SGD(momentum=0.9, nesterov=True)
model3.compile(loss="binary_crossentropy",
              optimizer=optimizer,
              metrics=["AUC"])
res_3 = model3.fit(X_train, y_train, epochs=30,
                validation_data=(X_valid, y_valid), verbose=0)
pd.DataFrame(res_3.history).iloc[-11:]
```

Out[91]:

	loss	auc	val_loss	val_auc
19	0.606591	0.931749	0.727074	0.647260
20	0.580834	0.938801	0.731760	0.630137
21	0.563246	0.934317	0.723209	0.606490
22	0.540377	0.939650	0.689933	0.663405
23	0.527437	0.930050	0.678146	0.568167
24	0.504876	0.937013	0.675902	0.609100
25	0.490270	0.934447	0.624446	0.668460
26	0.468684	0.945603	0.629763	0.632420
27	0.460482	0.937413	0.617241	0.593444
28	0.440436	0.945255	0.646946	0.555284
29	0.429026	0.944608	0.634787	0.614971

In [47]:

```
# iv
## (iv) dropout with probability 0.2
reset_session()
model4 = keras.models.Sequential()
model4.add(keras.layers.Dropout(rate=0.2))
for n_hidden in (200, 200, 100, 100, 50):
    model4.add(keras.layers.Dense(n_hidden, activation="elu",
                                 kernel_initializer="he_normal"))
    keras.layers.BatchNormalization()
    model4.add(keras.layers.Dropout(rate=0.2))
model4.add(keras.layers.Dense(1, activation="sigmoid"))
optimizer = keras.optimizers.SGD(momentum=0.9, nesterov=True)
model4.compile(loss="binary_crossentropy", optimizer=optimizer,
              metrics=["AUC"])
res_4 = model4.fit(X_train, y_train, epochs=30,
                validation_data=(X_valid, y_valid), verbose=0)
pd.DataFrame(res_4.history).iloc[-11:]
```

Out[47]:

	loss	auc	val_loss	val_auc
19	0.202673	0.758046	0.207132	0.763699

	loss	auc	val_loss	val_auc
20	0.195413	0.778679	0.211865	0.729126
21	0.195602	0.779355	0.213022	0.728637
22	0.192624	0.790284	0.208898	0.753098
23	0.198521	0.769023	0.211828	0.706458
24	0.197901	0.768586	0.209718	0.730267
25	0.197451	0.777869	0.204722	0.746575
26	0.190487	0.804407	0.206622	0.735323
27	0.193868	0.787001	0.209975	0.733040
28	0.187155	0.812326	0.218294	0.726680
29	0.190029	0.803976	0.220603	0.710209

In [48]:

```
# v
from functools import partial
RegularizedDense = partial(keras.layers.Dense,
                           activation="elu",
                           kernel_initializer="he_normal",
                           kernel_regularizer=keras.regularizers.l2(0.001))
reset_session()
model5 = keras.models.Sequential()
for n_hidden in (200, 200, 100, 100, 50):
    model5.add(RegularizedDense(n_hidden))
model5.add(keras.layers.Dense(1, activation="sigmoid"))
optimizer = keras.optimizers.SGD(momentum=0.9, nesterov=True)
model5.compile(loss="binary_crossentropy", optimizer=optimizer,
              metrics=["AUC"])
early_stopping_cb = keras.callbacks.EarlyStopping(monitor='auc',
                                                  mode='max', patience=10)
res_5 = model5.fit(X_train, y_train, epochs=30,
                validation_data =(X_valid, y_valid),
                callbacks=early_stopping_cb, verbose=0)
pd.DataFrame(res_5.history).iloc[-11:]
```

Out[48]:

	loss	auc	val_loss	val_auc
19	0.601281	0.933645	0.728743	0.651990
20	0.574888	0.941391	0.739134	0.593607
21	0.563113	0.933531	0.720304	0.609589
22	0.535514	0.939799	0.709157	0.639759
23	0.522086	0.931753	0.680604	0.582192
24	0.500186	0.937534	0.686488	0.607958
25	0.484851	0.936012	0.654018	0.641553
26	0.464267	0.947101	0.633350	0.632420
27	0.454924	0.939407	0.621614	0.603066
28	0.435375	0.945061	0.650451	0.562785

	loss	auc	val_loss	val_auc
29	0.423037	0.946966	0.639060	0.617254

In [49]:

```
# vi
reset_session()
model6 = keras.models.Sequential()
keras.layers.BatchNormalization()
model6.add(keras.layers.Dropout(rate=0.2))
for n_hidden in (200, 200, 100, 100, 50):
    model6.add(keras.layers.Dense(n_hidden, activation="elu",
                                  kernel_initializer="he_normal"))
    model6.add
    model6.add(keras.layers.Dropout(rate=0.2))
model6.add(keras.layers.Dense(1, activation="sigmoid"))
optimizer = keras.optimizers.SGD(momentum=0.9, nesterov=True)
model6.compile(loss="binary_crossentropy",
              optimizer=optimizer,
              metrics=["AUC"])
res_6 = model6.fit(X_train, y_train, epochs=30,
                   validation_data=(X_valid, y_valid), verbose=0)
pd.DataFrame(res_6.history).iloc[-11:]
```

Out[49]:

	loss	auc	val_loss	val_auc
19	0.202673	0.758046	0.207132	0.763699
20	0.195413	0.778679	0.211865	0.729126
21	0.195602	0.779355	0.213022	0.728637
22	0.192624	0.790284	0.208898	0.753098
23	0.198521	0.769023	0.211828	0.706458
24	0.197901	0.768586	0.209718	0.730267
25	0.197451	0.777869	0.204722	0.746575
26	0.190487	0.804407	0.206622	0.735323
27	0.193868	0.787001	0.209975	0.733040
28	0.187155	0.812326	0.218294	0.726680
29	0.190029	0.803976	0.220603	0.710209

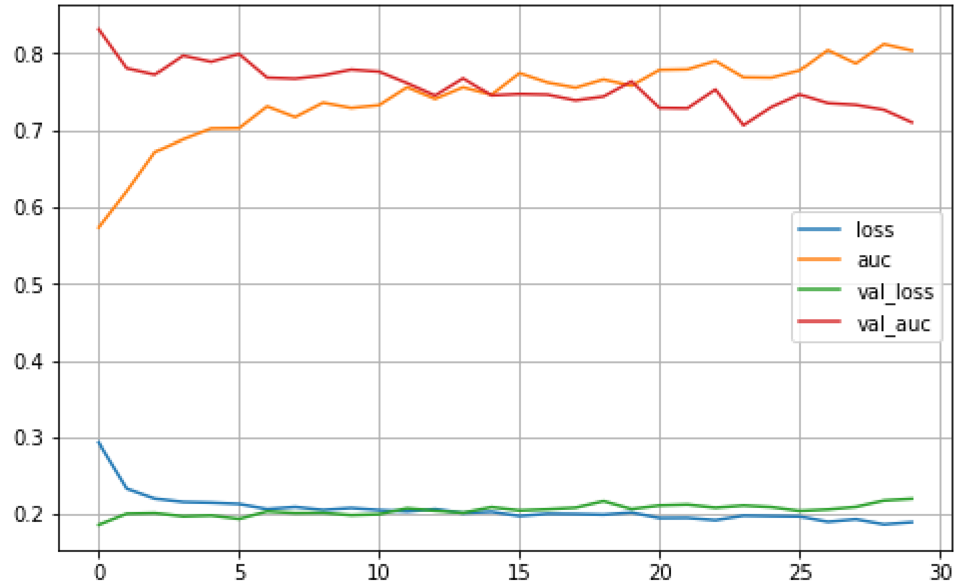
(e) [1 mark]

For the dropout model in (d)(iv) determine whether or not it is overfitting less than the model in (c).

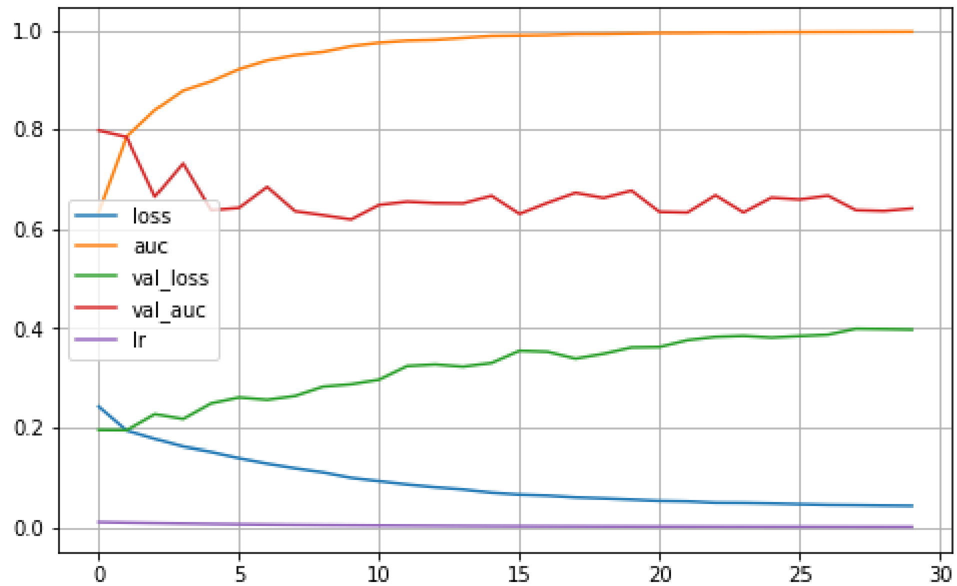
[Add your solution here]

In [50]:

```
#d(iv)
pd.DataFrame(res_4.history).plot(figsize=(8, 5))
plt.grid(True)
plt.show()
```



In [51]:
```
#c
pd.DataFrame(res.history).plot(figsize=(8, 5))
plt.grid(True)
plt.show()
```



The model in d(iv) is less overfitting than model in c.

(f) [1 mark]

Of the models in (c) and (d), one would now choose the best model according to the performance metric (validation AUC) to evaluate on the test set. But instead, evaluate the model in (d)(v) on the test set in terms of the AUC and confusion matrix (regardless of whether it is the best model given your results).

[Add your solution here]

In [53]:
```
# in (d)(v)
test_mse = model5.evaluate(X_test, y_test)
```

```
print(test_mse)
```

```
30/30 [==============================] - 0s 2ms/step - loss: 0.6175 - auc: 0.609
3
[0.6174782514572144, 0.6093239784240723]
```

In [52]:
```
test_mse_c = model.evaluate(X_test, y_test)
print(test_mse_c)
```

```
30/30 [==============================] - 0s 4ms/step - loss: 0.5307 - auc: 0.561
5
[0.5306558012962341, 0.5614603757858276]
```

The model in (d)(v) is better since it has higher AUC. The higher the AUC, the better the performance of the model at distinguishing between the positive and negative classes.

In [54]:
```
# confusion matirx of (d)(v)
from sklearn.metrics import confusion_matrix
y_true = y_test
y_pred = model5.predict(X_test)
confusion_matrix(y_true, (y_pred > 0.5))
```

Out[54]:
```
array([[854,  22],
       [ 52,   4]])
```

3. Time series using machine learning [14 marks]

Obtain daily values of the Japan/U.S. Foreign Exchange Rate (DEXJPUS) starting from Jan 1, 1990, to Jan 1, 2022, from FRED. This can be obtained using the code below or you can download the data as a csv file from Canvas.

In [55]:
```
import pandas as pd
import pandas_datareader as pdr
from datetime import datetime
data = pdr.get_data_fred('DEXJPUS', datetime(1990,1,1),datetime(2022,1,1))
```

In [56]:
```
data
```

Out[56]:

	DEXJPUS
DATE	
1990-01-01	NaN
1990-01-02	146.25
1990-01-03	145.70
1990-01-04	143.37
1990-01-05	143.82
...	...
2021-12-27	114.85
2021-12-28	114.75
2021-12-29	114.97

	DEXJPUS
DATE	
2021-12-30	115.17
2021-12-31	NaN

8350 rows × 1 columns

(a) [2 marks]

Create a training set (before 2010), a validation set (Jan 2010 to Dec 2015), and a test set (the rest of the data). Turn the time series data into a supervised learning dataset where the features are the value of the exchange rate in the last 10 days inclusive of the current day, and the target is the value of the exchange rate in the next day.

[Add your solution here]

In [57]:
```
data = data.dropna()
```

In [58]:
```
train = data[data.index < datetime(2010,1,1)]
test_raw = data[data.index > datetime(2010,1,1)]
valid = test_raw[test_raw.index < datetime(2016,1,1)]
test = test_raw[test_raw.index > datetime(2016,1,1)]
```

In [59]:
```
def ts_split(ts, feature_steps=10, target_steps=1):
    n_obs = len(ts) - feature_steps - target_steps + 1
    X = np.array([ts[idx:idx + feature_steps] for idx in range(n_obs)])
    y = np.array([ts[idx + feature_steps:idx + feature_steps + target_steps]
                  for idx in range(n_obs)])
    return X, y
```

In [60]:
```
X_train, y_train = ts_split(train, feature_steps=10, target_steps=1)
X_valid, y_valid = ts_split(valid, feature_steps=10, target_steps=1)
X_test, y_test = ts_split(test, feature_steps=10, target_steps=1)
```

In [61]:
```
X_train = X_train[:,:,-1]
X_valid = X_valid[:,:,-1]
X_test = X_test[:,:,-1]

y_train = y_train[:,:,-1]
y_valid = y_valid[:,:,-1]
y_test = y_test[:,:,-1]
```

(b) [3 marks]

Fit a random forest regressor to predict the value of the exchange rate in the next day. Using the test set, report the mean squared error and the accuracy for the movement direction.

Hint: You can calculate the accuracy of the movement direction by determining what the actual movement direction is and comparing it to the movement direction corresponding to the predicted value of the exchange rate. For instance, the movement direction of the test set `X_test` and `y_test` where a strictly up movement is `True` can be computed as follows.

In [62]:
```
movement_test = X_test[:,-1] < y_test.ravel()
```

[Add your solution here]

In [63]:
```
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error
regr = RandomForestRegressor(random_state=42)
regr.fit(X_train, y_train)
y_pred = regr.predict(X_test)
mse = mean_squared_error(y_test, y_pred)
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:4: DataConversionWa
rning: A column-vector y was passed when a 1d array was expected. Please change
the shape of y to (n_samples,), for example using ravel().
  after removing the cwd from sys.path.
```

In [64]:
```
mse
```

Out[64]:
```
0.3738088196839275
```

The mean squared error is 0.3738088196839275.

In [65]:
```
movement_pred = X_test[:,-1] < y_pred.ravel()
```

In [66]:
```
from sklearn.metrics import accuracy_score
accuracy_score(movement_test,movement_pred)
```

Out[66]:
```
0.5137861466039004
```

The accuracy score is 0.5137861466039004.

(c) [4 marks]

Repeat (b), but now fit a deep RNN with 2 recurrent layers of 20 and 20 neurons, and an output layer which is 1 dense neuron. Use 100 epochs and the Nadam optimizer. Comment on the result and the learning curve (the validation set is used for the learning curve).

[Add your solution here]

In [67]:
```
import numpy as np
import matplotlib as mpl
import matplotlib.pyplot as plt
import pandas as pd
%matplotlib inline

import tensorflow as tf
import tensorflow.keras as keras
```

In [68]:
```
reset_session()

model_rnn = keras.models.Sequential([
    keras.layers.SimpleRNN(20, return_sequences=True, input_shape=[None,1]),
    keras.layers.SimpleRNN(20),
```

```
    keras.layers.Dense(1)
])

model_rnn.compile(loss="mse", optimizer="nadam")
```

In [69]:

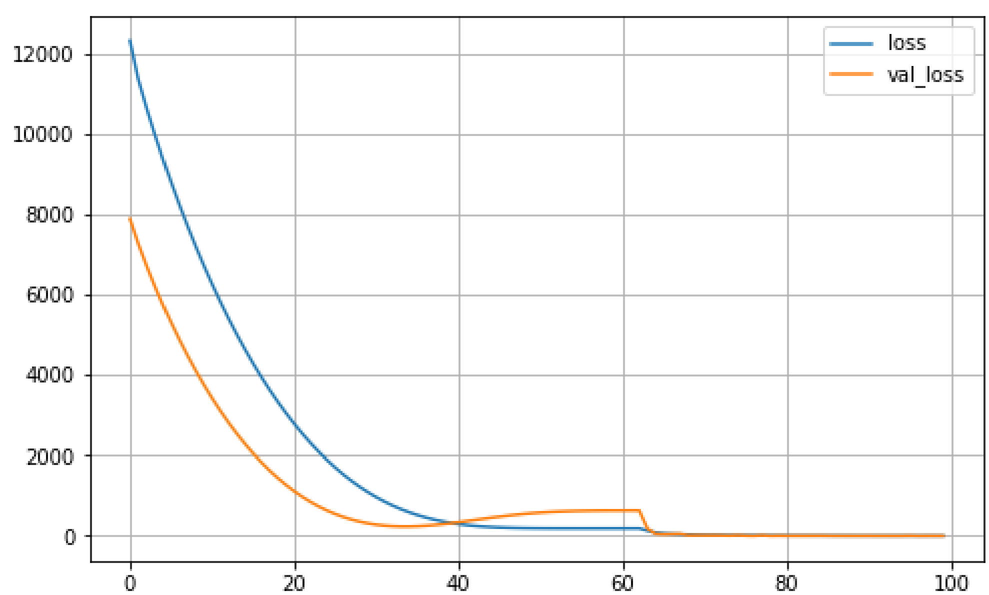
```
run = model_rnn.fit(X_train[..., np.newaxis], y_train, epochs=100,
                    validation_data=(X_valid[..., np.newaxis], y_valid),
                    verbose=0)
pd.DataFrame(run.history).iloc[-11:]
```

Out[69]:

	loss	val_loss
89	3.591288	1.419493
90	3.325146	2.030276
91	3.072608	1.041342
92	2.879261	0.744411
93	2.591041	0.558906
94	2.410072	1.589572
95	2.260275	4.533248
96	2.116478	0.650367
97	2.050760	1.693222
98	1.975142	1.852917
99	1.878468	1.274725

In [70]:

```
pd.DataFrame(run.history).plot(figsize=(8, 5))
plt.grid(True)
plt.show()
```



In [71]:

```
y_pred = model_rnn.predict(X_test[..., np.newaxis])
mse = mean_squared_error(y_test, y_pred)
print(mse)
```

```
0.4559698234802101
```

The mean squared error is 0.4559698234802101.

In [73]:
```
movement_pred = X_test[:,-1] < y_pred.ravel()
accuracy_score(movement_test,movement_pred)
```

Out[73]:
```
0.4969737726967048
```

The accuracy score is 0.4969737726967048.

(d) [5 marks]

Create a supervised learning dataset suitable for predicting 3 days ahead instead of 1 day ahead. Adjust the deep RNN in (c) so that it predicts 3 days ahead. Use 100 epochs and the Nadam optimizer. Using the test set, report the mean squared error and the accuracy for the movement direction for each of the 3 days ahead predictions. Comment on the result and the learning curve.

[Add your solution here]

In [74]:
```
X_train_3ahead, y_train_3ahead = ts_split(train, feature_steps=10, target_steps=
X_valid_3ahead, y_valid_3ahead = ts_split(valid, feature_steps=10, target_steps=
X_test_3ahead, y_test_3ahead = ts_split(test, feature_steps=10, target_steps=3)
```

In [75]:
```
X_train_3ahead = X_train_3ahead[:,:,-1]
X_valid_3ahead = X_valid_3ahead[:,:,-1]
X_test_3ahead = X_test_3ahead[:,:,-1]

y_train_3ahead = y_train_3ahead[:,:,-1]
y_valid_3ahead = y_valid_3ahead[:,:,-1]
y_test_3ahead = y_test_3ahead[:,:,-1]
```

In [76]:
```
reset_session()
model = keras.models.Sequential([
    keras.layers.SimpleRNN(20, return_sequences=True, input_shape=[None,1]),
    keras.layers.SimpleRNN(20),
    keras.layers.Dense(3)
])
model.compile(loss="mse", optimizer="nadam")
run_3ahead = model.fit(X_train_3ahead, y_train_3ahead, epochs=100,
                validation_data=(X_valid_3ahead, y_valid_3ahead),
                verbose=0)
```

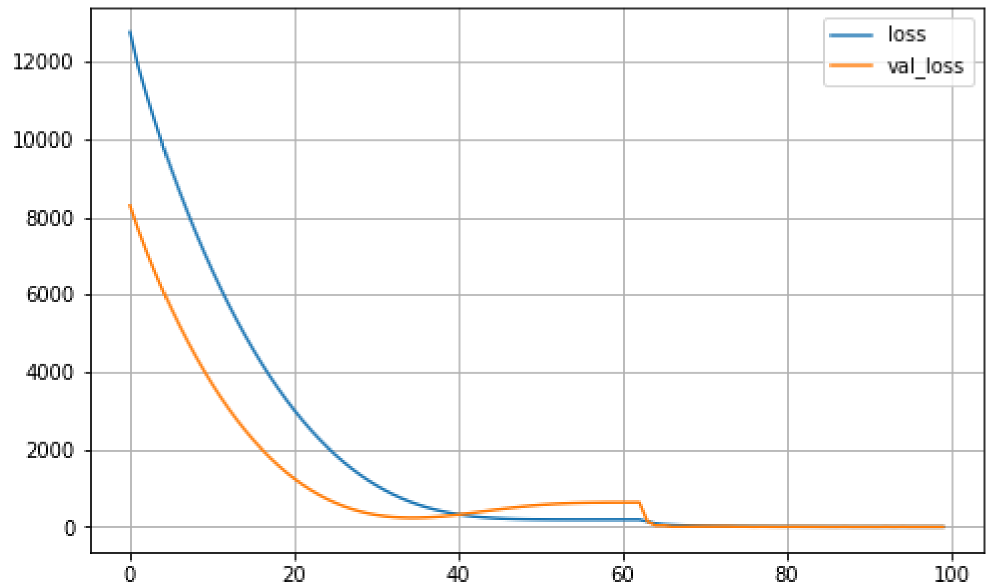
In [77]:
```
pd.DataFrame(run_3ahead.history).iloc[-11:]
```

Out[77]:

	loss	val_loss
89	4.023217	2.634159
90	3.848800	2.776287
91	3.478850	1.589141
92	3.422472	5.212845
93	3.076504	1.621511

	loss	val_loss
94	2.945980	4.762773
95	2.803193	2.063807
96	2.686125	2.201125
97	2.503860	2.098512
98	2.514158	1.557434
99	2.344383	1.996375

In [78]:
```
pd.DataFrame(run_3ahead.history).plot(figsize=(8, 5))
plt.grid(True)
plt.show()
```



In [80]:
```
y_pred_3ahead = model.predict(X_test_3ahead[..., np.newaxis])
mse_3ahead = mean_squared_error(y_test_3ahead, y_pred_3ahead)
```

In [81]:
```
mse_3ahead
```

Out[81]: 0.7284091227683439

The mean squared error is 0.7284091227683439.

In [82]:
```
movement_test_1 = X_test_3ahead[:,-1] < y_test_3ahead[:,0].ravel()
movement_test_2 = X_test_3ahead[:,-1] < y_test_3ahead[:,1].ravel()
movement_test_3 = X_test_3ahead[:,-1] < y_test_3ahead[:,2].ravel()
movement_test_d = np.concatenate((movement_test_1,movement_test_2,movement_test_

movement_pred_1 = X_test_3ahead[:,-1] < y_pred_3ahead[:,0].ravel()
movement_pred_2 = X_test_3ahead[:,-1] < y_pred_3ahead[:,1].ravel()
movement_pred_3 = X_test_3ahead[:,-1] < y_pred_3ahead[:,2].ravel()
movement_pred_d = np.concatenate((movement_pred_1,movement_pred_2,movement_pred_
```

In [83]:
```
accuracy_score(movement_test_d,movement_pred_d)
```

Out[83]: 0.4920314253647587

Conclusion: mse of model in (d) is bigger than the model in (c). The accuracy in (d) is smaller than the accuracy in (c). Hence, model (c) has better performance than mdoel (d).

The accuracy now is 0.4920314253647587.