lstm_models_colab

June 2, 2024

Importing neccessary libraries

1. **Numpy** for *linear algebra*
2. **Pandas** for reading csv files and DataFrame handling
3. **Tensorflow** for *machine learning*
4. **Keras** for defining the *LSTM model architecture* and regularization
5. Functions such as **train_test_split** for dividing the dataset into training and test set and **GridSearchCV** to tune hyperparameters across a grid of values.
6. **MinMaxScaler** to scale the variable values to a range of $[0, 1]$.
7. **matplotlib** for plotting results

[ ]:
```
pip install scikeras
```

[ ]:
```
import numpy as np
import pandas as pd
import tensorflow as tf
from keras.models import Sequential
from keras.layers import Dense, LSTM, Dropout, Input
from sklearn.model_selection import train_test_split, GridSearchCV
from keras.callbacks import EarlyStopping
from keras.utils import to_categorical
from sklearn.preprocessing import MinMaxScaler
from scikeras.wrappers import KerasClassifier
import matplotlib.pyplot as plt
from keras.regularizers import l2
from sklearn.metrics import confusion_matrix, ConfusionMatrixDisplay
from keras.callbacks import EarlyStopping
from sklearn.metrics import accuracy_score
```

0.1 Setting Device to GPU

Since the model is run in Google Colab with an external GPU for increased computational ability the device which is used needs to be defined:

[ ]:
```
device_name = tf.test.gpu_device_name()
if device_name != '/device:GPU:0':
    print('GPU not found')
else:
```

```
    print(f'GPU found at: {device_name}')
```

1 Data Loading

[ ]:
```
file_path = '/content/final_dataset.csv'
df = pd.read_csv(file_path)

dataset = df.values[:, 0:].astype('float64')

diff = dataset[:,0:1]
```

[ ]:
```
np.random.seed(42)
tf.random.set_seed(42)
```

2 Output Variable Transformation and Data Scaling

[ ]:
```
# 34.1 quantile: -0.0021999999999999
# 65 quantile:  0.0021999999999999

def categorize_diff(diff):
    if diff < -0.0021999999999999:
        return 0  # Price fall bucket
    elif diff > 0.0021999999999999:
        return 2  # Price rise bucket
    else:
        return 1  # No action bucket

y_categories = np.array([categorize_diff(pc) for pc in diff])
```

[ ]:
```
y_categories = to_categorical(y_categories)

scaler = MinMaxScaler(feature_range=(0, 1))
dataset = scaler.fit_transform(dataset[:, 1:])
```

3 Conversion to Tensor

[ ]:
```
def create_dataset(dataset, time_steps = 1):
    dataX = []
    for i in range(len(dataset) - time_steps):
        a = dataset[i:(i + time_steps), :]
        dataX.append(a)
    return np.array(dataX)
```

4 1st Iteration

[ ]:
```
time_steps = 15

dataX = create_dataset(dataset, time_steps)

dataX = np.reshape(dataX, (dataX.shape[0], time_steps, dataset.shape[1]))

X = dataX
y = y_categories[time_steps:]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
↪shuffle=False, random_state = 42)
```

[ ]:
```
def create_model(units1 = 128, dropout_rate1 = 0.1, batch_size = 32):
    model = Sequential([
        Input(shape = (X_train.shape[1], X_train.shape[2])),
        LSTM(units1, return_sequences = False),
        Dropout(dropout_rate1),
        Dense(3, activation = 'softmax')
    ])
    model.compile(optimizer = 'adam', loss = 'categorical_crossentropy',␣
↪metrics = ['accuracy'])
    return model
```

[ ]:
```
model = KerasClassifier(model = create_model, epochs = 75, verbose = 0, shuffle␣
↪= False, random_state = 42)
```

[ ]:
```
param_grid = {
    'model__units1': [32, 64, 128],
    'model__dropout_rate1': [0.1, 0.2, 0.3, 0.4],
    'batch_size': [128, 64, 32]
}
```

[ ]:
```
grid = GridSearchCV(estimator=model, param_grid=param_grid, cv = 5, n_jobs = -1)
```

[ ]:
```
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
↪start_from_epoch = 10, restore_best_weights = True)

grid_result = grid.fit(X_train, y_train, callbacks = [early_stopping],␣
↪validation_split = 0.2)
```

[ ]:
```
best_params = grid_result.best_params_

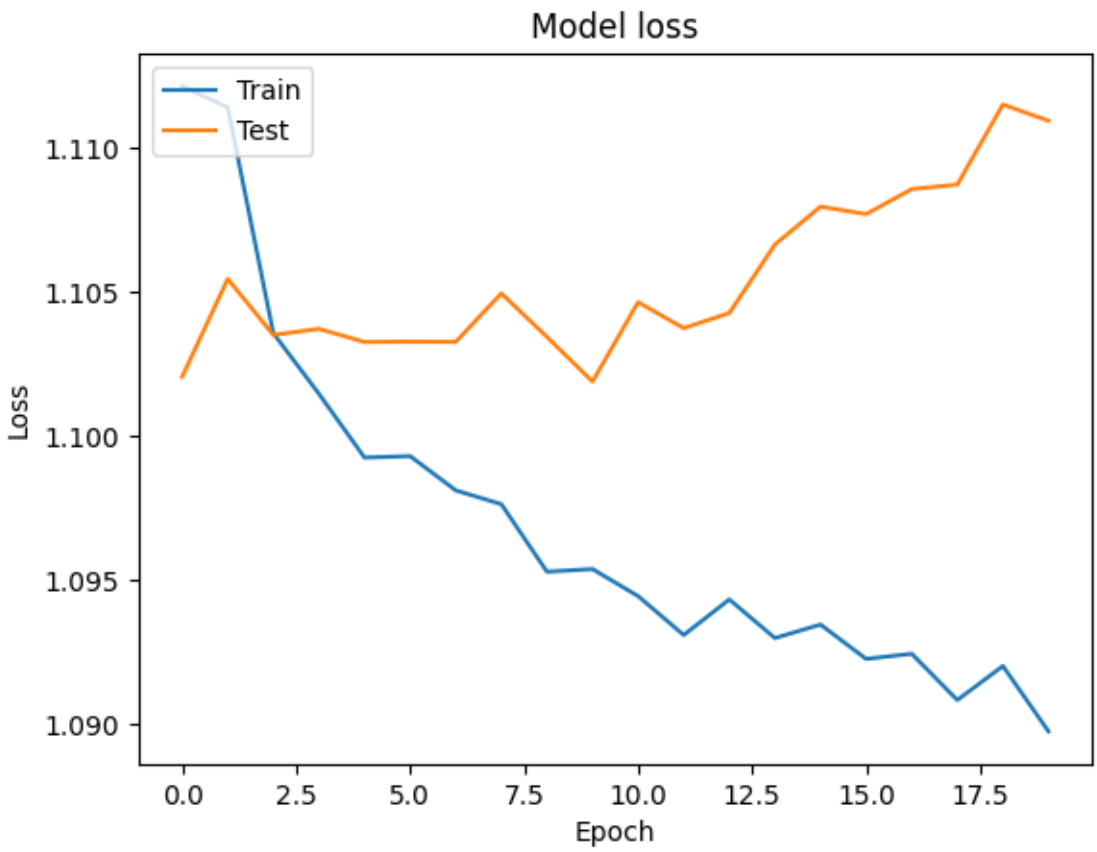
print(best_params)
```

```
{'batch_size': 128, 'model__dropout_rate1': 0.1, 'model__units1': 32}
```

[ ]:
```
best_model = create_model(batch_size = best_params['batch_size'],
                          dropout_rate1 = best_params['model__dropout_rate1'],
                          units1 = best_params['model__units1'],
                          )
```

[ ]:
```
early_stopping_manual = EarlyStopping(monitor='val_loss', patience = 10,␣
 ↪restore_best_weights = True)
history = best_model.fit(X_train, y_train,
                         epochs = 75,
                         batch_size = 128, # remember to change if needed␣
 ↪(default = 32)
                         validation_data = (X_test, y_test),
                         shuffle = False,
                         callbacks = [early_stopping_manual],
                         verbose = 0
                         )
```

[ ]:
```
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```



[ ]:
```
y_pred = best_model.predict(X_test)

actual_categories = np.argmax(y_test, axis=1)

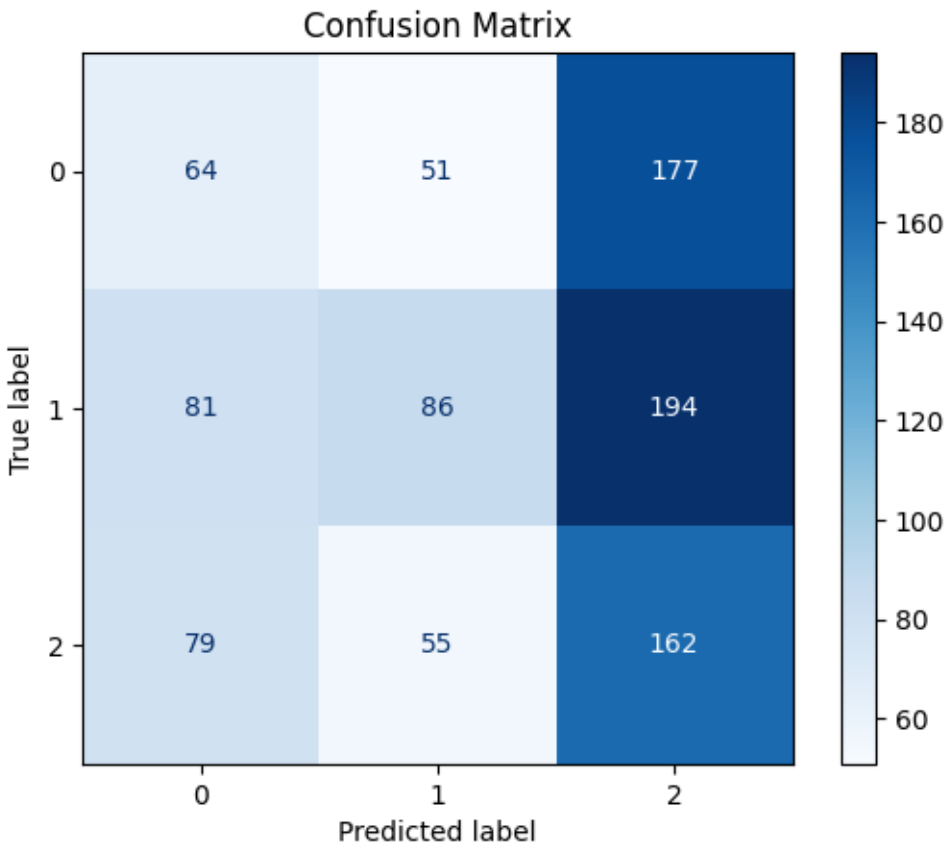
predicted_categories = np.argmax(y_pred, axis=1)

cm = confusion_matrix(actual_categories, predicted_categories)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1, 2])

plt.figure(figsize=(10, 7))
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()
```

```
30/30              0s 5ms/step
```

```
<Figure size 1000x700 with 0 Axes>
```



[ ]:
```
file_path = '/content/usd_eur_raw.csv'
df_raw_exchange = pd.read_csv(file_path)

df_raw_exchange = df_raw_exchange['usd_eur_exchange'].pct_change()

df_raw_exchange = df_raw_exchange.iloc[3:-1]
```

[ ]:
```
def compute_hit_rate(signals, percent_changes):
    correct_signals = 0
    total_signals = len(signals)

    for signal, percent_change in zip(signals, percent_changes):
        if (signal == 0 and percent_change < 0) or (signal == 2 and␣
 ↪percent_change > 0):
            correct_signals += 1
        elif signal == 1:
            total_signals -= 1

    return correct_signals / total_signals if total_signals > 0 else 0
```

```
def backtest(actions, percent_changes):
    cash = 100
    position = 0  # Current position: 0 for flat, -1 for short, 1 for long
    portfolio_value = []

    for action, percent_change in zip(actions, percent_changes):
        if action == 0:  # Sell
            position = -100  # Set position to short
            cash += position * percent_change  # Sell shares
        elif action == 1:  # Flat
            position = 0  # Set position to flat
            cash += 0  # No action
        elif action == 2:  # Buy
            position = 100  # Set position to long
            cash += position * percent_change  # Buy shares

        portfolio_value.append(cash)  # Calculate portfolio value

    return portfolio_value

def run_single_iteration(X_train, y_train, X_test, y_test, best_params):
    best_model = create_model(batch_size = best_params['batch_size'],
                              dropout_rate1 =␣
 ↪best_params['model__dropout_rate1'],
                              units1 = best_params['model__units1']
    )

    early_stopping_manual = EarlyStopping(monitor='val_loss', patience = 10,␣
 ↪restore_best_weights = True)
    history = best_model.fit(X_train, y_train,
                             epochs=75,
                             validation_data=(X_test, y_test),
                             batch_size = 128,
                             shuffle=False,
                             callbacks=[early_stopping_manual],
                             verbose=0)

    predictions = best_model.predict(X_test)
    predicted_categories = np.argmax(predictions, axis=1)

    y_test_labels = np.argmax(y_test, axis=1)

    accuracy = accuracy_score(y_test_labels, predicted_categories)

    signals = predicted_categories
    percent_changes = np.array(df_raw_exchange.iloc[-len(y_test):])
```

```
    portfolio_value = backtest(signals, percent_changes)
    hit_rate = compute_hit_rate(signals, percent_changes)
    num_trades = np.sum((signals == 0) | (signals == 2))

    return portfolio_value, accuracy, hit_rate, num_trades

iterations = 50

final_portfolio_values = []
accuracies = []
hit_rates = []
trade_counts = []

for i in range(iterations):
    print(f"Running iteration {i+1}/{iterations}")
    portfolio_value, accuracy, hit_rate, num_trades =␣
 ↪run_single_iteration(X_train, y_train, X_test, y_test, best_params)
    final_portfolio_values.append(portfolio_value[-1])
    accuracies.append(accuracy)
    hit_rates.append(hit_rate)
    trade_counts.append(num_trades)
    print(f"Iteration {i+1} - Final Portfolio Value: {portfolio_value[-1]},␣
 ↪Accuracy: {accuracy}, Hit Rate: {hit_rate}, Trades: {num_trades}")

average_final_value = np.mean(final_portfolio_values)
std_final_value = np.std(final_portfolio_values)

average_accuracy = np.mean(accuracies)
average_hit_rate = np.mean(hit_rates)
average_num_trades = np.mean(trade_counts)

print("Average Final Portfolio Value:")
print(average_final_value)
print('Standard Deviation of Final Values:')
print(std_final_value)
print('Average Accuracy:')
print(average_accuracy)
print('Average Hit Rate:')
print(average_hit_rate)
print('Average No. of Trades:')
print(average_num_trades)
```

```
Running iteration 1/50
30/30             0s 5ms/step
Iteration 1 - Final Portfolio Value: 130.9705919301891, Accuracy:
0.339304531085353, Hit Rate: 0.540084388185654, Trades: 948
```

```
Running iteration 2/50
30/30             0s 5ms/step
Iteration 2 - Final Portfolio Value: 125.08088819532354, Accuracy:
0.37302423603793466, Hit Rate: 0.5284974093264249, Trades: 579
Running iteration 3/50
30/30             1s 22ms/step
Iteration 3 - Final Portfolio Value: 88.20719257530371, Accuracy:
0.3424657534246575, Hit Rate: 0.4577922077922078, Trades: 308
Running iteration 4/50
30/30             1s 16ms/step
Iteration 4 - Final Portfolio Value: 92.43205228245992, Accuracy:
0.38461538461538464, Hit Rate: 0.4423076923076923, Trades: 52
Running iteration 5/50
30/30             1s 22ms/step
Iteration 5 - Final Portfolio Value: 109.52243784995402, Accuracy:
0.35089567966280294, Hit Rate: 0.5020833333333333, Trades: 480
Running iteration 6/50
30/30             0s 5ms/step
Iteration 6 - Final Portfolio Value: 87.55812141998564, Accuracy:
0.3561643835616438, Hit Rate: 0.48823529411764705, Trades: 340
Running iteration 7/50
30/30             1s 25ms/step
Iteration 7 - Final Portfolio Value: 89.89001294208788, Accuracy:
0.3656480505795574, Hit Rate: 0.4880239520958084, Trades: 334
Running iteration 8/50
30/30             1s 19ms/step
Iteration 8 - Final Portfolio Value: 102.53552103840862, Accuracy:
0.3835616438356164, Hit Rate: 0.5238095238095238, Trades: 126
Running iteration 9/50
30/30             1s 20ms/step
Iteration 9 - Final Portfolio Value: 94.85278990754041, Accuracy:
0.303477344573235, Hit Rate: 0.4956043956043956, Trades: 910
Running iteration 10/50
30/30             0s 5ms/step
Iteration 10 - Final Portfolio Value: 95.44475052688146, Accuracy:
0.3772391991570074, Hit Rate: 0.125, Trades: 8
Running iteration 11/50
30/30             1s 25ms/step
Iteration 11 - Final Portfolio Value: 91.75711221099321, Accuracy:
0.3055848261327713, Hit Rate: 0.4962805526036132, Trades: 941
Running iteration 12/50
30/30             0s 5ms/step
Iteration 12 - Final Portfolio Value: 97.58524048480199, Accuracy:
0.31612223393045313, Hit Rate: 0.5017221584385764, Trades: 871
Running iteration 13/50
30/30             0s 12ms/step
Iteration 13 - Final Portfolio Value: 90.65018235534289, Accuracy:
0.35511064278187565, Hit Rate: 0.4814004376367615, Trades: 457
```

```
Running iteration 14/50
30/30             0s 13ms/step
Iteration 14 - Final Portfolio Value: 100.67664854786567, Accuracy:
0.3804004214963119, Hit Rate: 1.0, Trades: 2
Running iteration 15/50
30/30             0s 5ms/step
Iteration 15 - Final Portfolio Value: 89.07977904574149, Accuracy:
0.2971548998946259, Hit Rate: 0.47664543524416136, Trades: 942
Running iteration 16/50
30/30             0s 5ms/step
Iteration 16 - Final Portfolio Value: 84.59602501712635, Accuracy:
0.34562697576396206, Hit Rate: 0.4649122807017544, Trades: 684
Running iteration 17/50
30/30             0s 5ms/step
Iteration 17 - Final Portfolio Value: 99.0169484989736, Accuracy:
0.3076923076923077, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 18/50
30/30             0s 5ms/step
Iteration 18 - Final Portfolio Value: 102.22468783450287, Accuracy:
0.3287671232876712, Hit Rate: 0.5072463768115942, Trades: 759
Running iteration 19/50
30/30             0s 5ms/step
Iteration 19 - Final Portfolio Value: 93.87598147606109, Accuracy:
0.3466807165437302, Hit Rate: 0.48586118251928023, Trades: 389
Running iteration 20/50
30/30             0s 5ms/step
Iteration 20 - Final Portfolio Value: 106.63974938987032, Accuracy:
0.3203371970495258, Hit Rate: 0.5134770889487871, Trades: 742
Running iteration 21/50
30/30             0s 5ms/step
Iteration 21 - Final Portfolio Value: 91.30415604686907, Accuracy:
0.3667017913593256, Hit Rate: 0.4583333333333333, Trades: 240
Running iteration 22/50
30/30             0s 5ms/step
Iteration 22 - Final Portfolio Value: 100.46991353981329, Accuracy:
0.3540569020021075, Hit Rate: 0.5016778523489933, Trades: 596
Running iteration 23/50
30/30             0s 5ms/step
Iteration 23 - Final Portfolio Value: 99.0169484989736, Accuracy:
0.3076923076923077, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 24/50
30/30             0s 5ms/step
Iteration 24 - Final Portfolio Value: 102.64697607808684, Accuracy:
0.3540569020021075, Hit Rate: 0.537467700258398, Trades: 387
Running iteration 25/50
30/30             0s 5ms/step
Iteration 25 - Final Portfolio Value: 104.39901635598461, Accuracy:
0.3129610115911486, Hit Rate: 0.4962962962962963, Trades: 945
```

```
Running iteration 26/50
30/30             0s 5ms/step
Iteration 26 - Final Portfolio Value: 98.47467172809864, Accuracy:
0.37829293993677554, Hit Rate: 0.4881889763779528, Trades: 127
Running iteration 27/50
30/30             0s 5ms/step
Iteration 27 - Final Portfolio Value: 116.43583393102845, Accuracy:
0.3256059009483667, Hit Rate: 0.5026343519494204, Trades: 949
Running iteration 28/50
30/30             0s 5ms/step
Iteration 28 - Final Portfolio Value: 96.61591336516825, Accuracy:
0.31401475237091675, Hit Rate: 0.5017964071856288, Trades: 835
Running iteration 29/50
30/30             0s 5ms/step
Iteration 29 - Final Portfolio Value: 106.47930813305638, Accuracy:
0.3909378292939937, Hit Rate: 0.5263157894736842, Trades: 95
Running iteration 30/50
30/30             0s 5ms/step
Iteration 30 - Final Portfolio Value: 107.6155580013376, Accuracy:
0.3951527924130664, Hit Rate: 0.5565610859728507, Trades: 221
Running iteration 31/50
30/30             0s 5ms/step
Iteration 31 - Final Portfolio Value: 101.15394228477201, Accuracy:
0.35511064278187565, Hit Rate: 0.49506903353057197, Trades: 507
Running iteration 32/50
30/30             0s 5ms/step
Iteration 32 - Final Portfolio Value: 91.12278679309256, Accuracy:
0.3656480505795574, Hit Rate: 0.4074074074074074, Trades: 108
Running iteration 33/50
30/30             0s 5ms/step
Iteration 33 - Final Portfolio Value: 100.37532049499846, Accuracy:
0.3192834562697576, Hit Rate: 0.5043103448275862, Trades: 928
Running iteration 34/50
30/30             0s 5ms/step
Iteration 34 - Final Portfolio Value: 98.95369769049677, Accuracy:
0.3761854583772392, Hit Rate: 0.5, Trades: 28
Running iteration 35/50
30/30             0s 5ms/step
Iteration 35 - Final Portfolio Value: 99.0169484989736, Accuracy:
0.3076923076923077, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 36/50
30/30             0s 5ms/step
Iteration 36 - Final Portfolio Value: 112.0736660464981, Accuracy:
0.3171759747102213, Hit Rate: 0.5116525423728814, Trades: 944
Running iteration 37/50
30/30             0s 5ms/step
Iteration 37 - Final Portfolio Value: 83.12114133930876, Accuracy:
0.34562697576396206, Hit Rate: 0.453125, Trades: 512
```

```
Running iteration 38/50
30/30             0s 5ms/step
Iteration 38 - Final Portfolio Value: 98.59226395983322, Accuracy:
0.38672286617492097, Hit Rate: 0.5252525252525253, Trades: 99
Running iteration 39/50
30/30             0s 5ms/step
Iteration 39 - Final Portfolio Value: 89.59355612481805, Accuracy:
0.3087460484720759, Hit Rate: 0.48322147651006714, Trades: 894
Running iteration 40/50
30/30             0s 5ms/step
Iteration 40 - Final Portfolio Value: 99.10844703818681, Accuracy:
0.3487881981032666, Hit Rate: 0.49673202614379086, Trades: 459
Running iteration 41/50
30/30             0s 5ms/step
Iteration 41 - Final Portfolio Value: 98.43034458563427, Accuracy:
0.3066385669125395, Hit Rate: 0.5, Trades: 948
Running iteration 42/50
30/30             0s 5ms/step
Iteration 42 - Final Portfolio Value: 94.00660656516622, Accuracy:
0.38777660695468913, Hit Rate: 0.47619047619047616, Trades: 84
Running iteration 43/50
30/30             0s 5ms/step
Iteration 43 - Final Portfolio Value: 107.00363859868915, Accuracy:
0.3635405690200211, Hit Rate: 0.5230414746543779, Trades: 434
Running iteration 44/50
30/30             0s 5ms/step
Iteration 44 - Final Portfolio Value: 96.18631372222343, Accuracy:
0.3171759747102213, Hit Rate: 0.4982973893303065, Trades: 881
Running iteration 45/50
30/30             0s 5ms/step
Iteration 45 - Final Portfolio Value: 72.51810405215407, Accuracy:
0.28872497365648053, Hit Rate: 0.4682981090100111, Trades: 899
Running iteration 46/50
30/30             0s 5ms/step
Iteration 46 - Final Portfolio Value: 101.61139815840868, Accuracy:
0.30979978925184404, Hit Rate: 0.5032327586206896, Trades: 928
Running iteration 47/50
30/30             0s 5ms/step
Iteration 47 - Final Portfolio Value: 107.0422668512316, Accuracy:
0.31401475237091675, Hit Rate: 0.49730312837108953, Trades: 927
Running iteration 48/50
30/30             0s 5ms/step
Iteration 48 - Final Portfolio Value: 101.21858906178979, Accuracy:
0.3108535300316122, Hit Rate: 0.5057603686635944, Trades: 868
Running iteration 49/50
30/30             0s 5ms/step
Iteration 49 - Final Portfolio Value: 108.25130583771814, Accuracy:
0.36143308746048475, Hit Rate: 0.5031185031185031, Trades: 481
```

```
Running iteration 50/50
30/30             0s 5ms/step
Iteration 50 - Final Portfolio Value: 111.60253607771843, Accuracy:
0.3677555321390938, Hit Rate: 0.5263157894736842, Trades: 380
Average Final Portfolio Value:
99.34075765979085
Standard Deviation of Final Values:
9.994642484009807
Average Accuracy:
0.34276080084299254
Average Hit Rate:
0.49942651379320596
Average No. of Trades:
568.46
```

5 2nd Iteration

[ ]:
```
time_steps = 15

dataX = create_dataset(dataset, time_steps)

dataX = np.reshape(dataX, (dataX.shape[0], time_steps, dataset.shape[1]))

X = dataX
y = y_categories[time_steps:]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
 ↪shuffle=False)
```

[ ]:
```
def create_model_3(units1 = 128, dropout_rate1 = 0.3, batch_size = 32, l2_value␣
 ↪= 0.01):
    model = Sequential([
        Input(shape = (X_train.shape[1], X_train.shape[2])),
        LSTM(units1, return_sequences = True),
        Dropout(dropout_rate1),
        Dense(3, activation = 'softmax', kernel_regularizer = l2(l2_value))
    ])
    model.compile(optimizer = 'adam', loss = 'categorical_crossentropy',␣
 ↪metrics = ['accuracy'])
    return model
```

[ ]:
```
model_3 = KerasClassifier(model = create_model_3, epochs = 75, verbose = 0,␣
 ↪shuffle = False, random_state = 42)
```

[ ]:
```
param_grid_model3 = {
    'model__units1': [32, 64, 128],
    'model__dropout_rate1': [0.4, 0.3, 0.2],
    'batch_size': [32, 64, 128],
```

```
    'model__l2_value': [0.1, 0.01, 0.001]
}
```

[ ]:
```
grid_model_3 = GridSearchCV(estimator = model_3, param_grid =␣
↪param_grid_model3, cv = 5, n_jobs = -1)
```

[ ]:
```
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
↪start_from_epoch = 10, restore_best_weights = True)

grid_result_model_3 = grid_model_3.fit(X_train, y_train, validation_split = 0.
↪2, callbacks = [early_stopping])
```

[ ]:
```
best_params_model_3 = grid_result_model_3.best_params_

print(best_params_model_3)
```

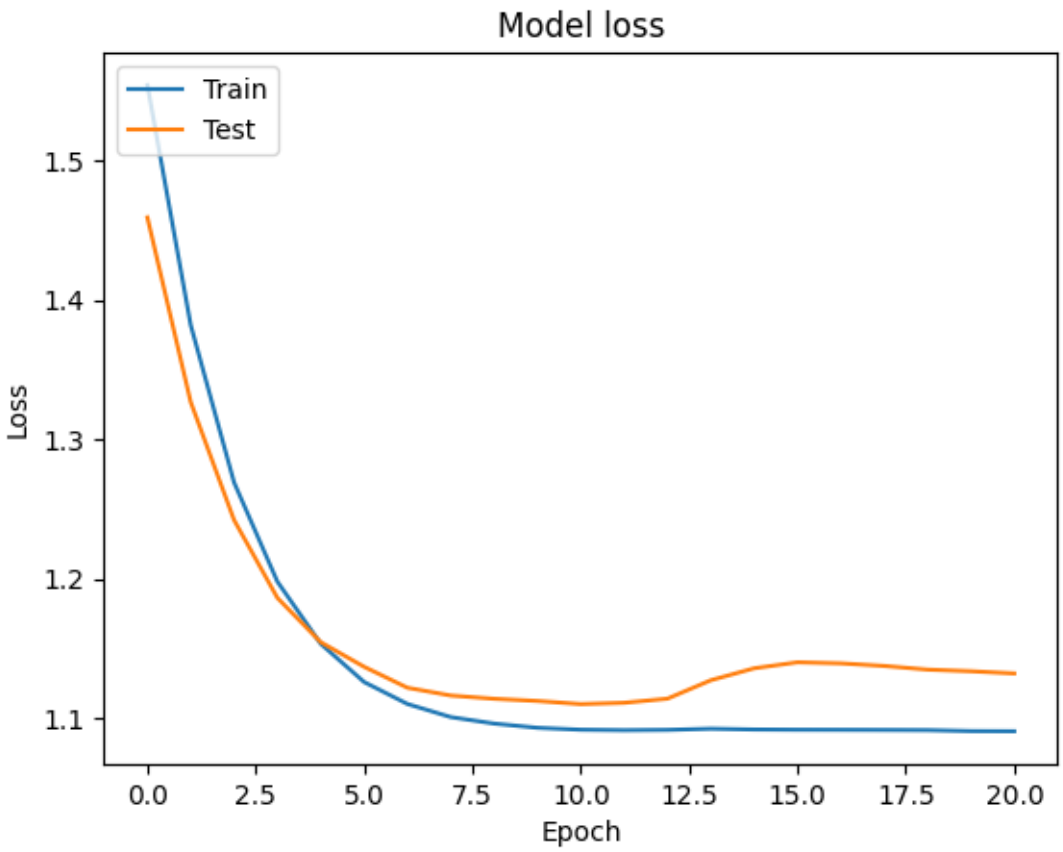
```
{'batch_size': 128, 'model__dropout_rate1': 0.4, 'model__l2_value': 0.1,
'model__units1': 128}
```

[ ]:
```
best_model_3 = create_model_3(units1 = best_params_model_3['model__units1'],
                              dropout_rate1 =␣
↪best_params_model_3['model__dropout_rate1'],
                              batch_size = best_params_model_3['batch_size'],
                              l2_value = best_params_model_3['model__l2_value'],
                              )
```

[ ]:
```
early_stopping_manual = EarlyStopping(monitor='val_loss', patience = 10,␣
↪restore_best_weights = True)

history_model_3 = best_model_3.fit(X_train, y_train,
                             epochs = 75,
                             validation_data = (X_test, y_test),
                                       batch_size = 128,
                            callbacks = [early_stopping_manual],
                             verbose = 0)
```

[ ]:
```
plt.plot(history_model_3.history['loss'])
plt.plot(history_model_3.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```



[ ]:
```
y_pred = best_model_3.predict(X_test)

actual_categories = np.argmax(y_test, axis=1)

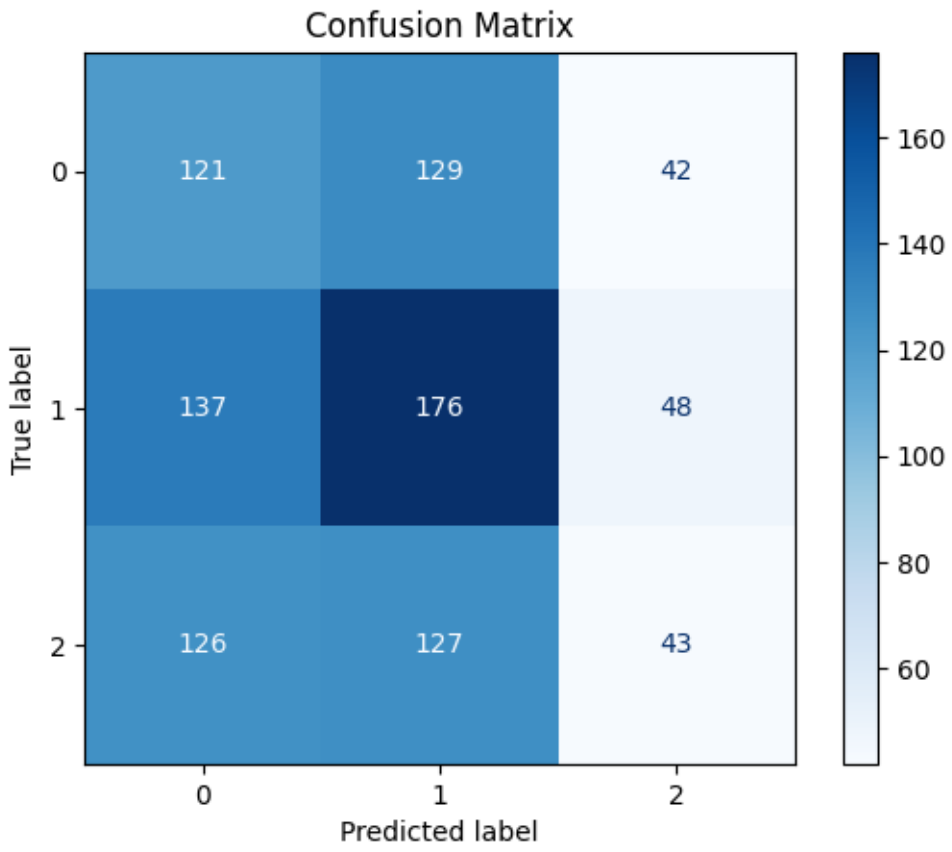
predicted_categories = np.argmax(y_pred, axis=1)

cm = confusion_matrix(actual_categories, predicted_categories)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1, 2])

plt.figure(figsize=(10, 7))
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()
```

```
30/30              1s 12ms/step
```

```
<Figure size 1000x700 with 0 Axes>
```



[ ]:
```
def compute_hit_rate(signals, percent_changes):
    correct_signals = 0
    total_signals = len(signals)

    for signal, percent_change in zip(signals, percent_changes):
        if (signal == 0 and percent_change < 0) or (signal == 2 and␣
 ↪percent_change > 0):
            correct_signals += 1
        elif signal == 1:
            total_signals -= 1

    return correct_signals / total_signals if total_signals > 0 else 0

def backtest(actions, percent_changes):
    cash = 100
    position = 0  # Current position: 0 for flat, -1 for short, 1 for long
    portfolio_value = []

    for action, percent_change in zip(actions, percent_changes):
```

```
        if action == 0:  # Sell
            position = -100  # Set position to short
            cash += position * percent_change  # Sell shares
        elif action == 1:  # Flat
            position = 0  # Set position to flat
            cash += 0  # No action
        elif action == 2:  # Buy
            position = 100  # Set position to long
            cash += position * percent_change  # Buy shares

        portfolio_value.append(cash)  # Calculate portfolio value

    return portfolio_value

def run_single_iteration(X_train, y_train, X_test, y_test, best_params):
    best_model_3 = create_model_3(units1 = best_params_model_3['model__units1'],
                           dropout_rate1 =␣
 ↪best_params_model_3['model__dropout_rate1'],
                           batch_size = best_params_model_3['batch_size'],
                           l2_value = best_params_model_3['model__l2_value']
                           )

    early_stopping_manual = EarlyStopping(monitor='val_loss', patience = 10,␣
 ↪restore_best_weights = True)

    history_model_3 = best_model_3.fit(X_train, y_train,
                          epochs = 100,
                          validation_data = (X_test, y_test),
                                    batch_size = 128,
                         callbacks = [early_stopping_manual],
                          verbose = 0)

    predictions = best_model_3.predict(X_test)
    predicted_categories = np.argmax(predictions, axis=1)

    y_test_labels = np.argmax(y_test, axis=1)

    accuracy = accuracy_score(y_test_labels, predicted_categories)

    signals = predicted_categories
    percent_changes = np.array(df_raw_exchange.iloc[-len(y_test):])

    portfolio_value = backtest(signals, percent_changes)
    hit_rate = compute_hit_rate(signals, percent_changes)
    num_trades = np.sum((signals == 0) | (signals == 2))
```

```
    return portfolio_value, accuracy, hit_rate, num_trades

iterations = 50

final_portfolio_values = []
accuracies = []
hit_rates = []
trade_counts = []

for i in range(iterations):
    print(f"Running iteration {i+1}/{iterations}")
    portfolio_value, accuracy, hit_rate, num_trades =␣
 ↪run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_3)
    final_portfolio_values.append(portfolio_value[-1])
    accuracies.append(accuracy)
    hit_rates.append(hit_rate)
    trade_counts.append(num_trades)
    print(f"Iteration {i+1} - Final Portfolio Value: {portfolio_value[-1]},␣
 ↪Accuracy: {accuracy}, Hit Rate: {hit_rate}, Trades: {num_trades}")

average_final_value = np.mean(final_portfolio_values)
std_final_value = np.std(final_portfolio_values)

average_accuracy = np.mean(accuracies)
average_hit_rate = np.mean(hit_rates)
average_num_trades = np.mean(trade_counts)

print("Average Final Portfolio Value:")
print(average_final_value)
print('Standard Deviation of Final Values:')
print(std_final_value)
print('Average Accuracy:')
print(average_accuracy)
print('Average Hit Rate:')
print(average_hit_rate)
print('Average No. of Trades:')
print(average_num_trades)
```

```
Running iteration 1/50
30/30             1s 11ms/step
Iteration 1 - Final Portfolio Value: 92.99336673141849, Accuracy:
0.34562697576396206, Hit Rate: 0.4956521739130435, Trades: 690
Running iteration 2/50
30/30             1s 11ms/step
Iteration 2 - Final Portfolio Value: 97.36188788517133, Accuracy:
0.3582718651211802, Hit Rate: 0.49538461538461537, Trades: 650
Running iteration 3/50
```

```
30/30            1s 11ms/step
Iteration 3 - Final Portfolio Value: 106.47416323425908, Accuracy:
0.3698630136986301, Hit Rate: 0.5081168831168831, Trades: 616
Running iteration 4/50
30/30            1s 11ms/step
Iteration 4 - Final Portfolio Value: 98.08279287007241, Accuracy:
0.35511064278187565, Hit Rate: 0.5073529411764706, Trades: 680
Running iteration 5/50
30/30            1s 11ms/step
Iteration 5 - Final Portfolio Value: 89.27737583290553, Accuracy:
0.3224446786090622, Hit Rate: 0.4894459102902375, Trades: 758
Running iteration 6/50
30/30            1s 11ms/step
Iteration 6 - Final Portfolio Value: 99.67983201742811, Accuracy:
0.36143308746048475, Hit Rate: 0.4927536231884058, Trades: 483
Running iteration 7/50
30/30            1s 11ms/step
Iteration 7 - Final Portfolio Value: 95.75321354014066, Accuracy:
0.34562697576396206, Hit Rate: 0.4875, Trades: 560
Running iteration 8/50
30/30            1s 11ms/step
Iteration 8 - Final Portfolio Value: 92.98909282387552, Accuracy:
0.3466807165437302, Hit Rate: 0.49779086892488955, Trades: 679
Running iteration 9/50
30/30            1s 11ms/step
Iteration 9 - Final Portfolio Value: 101.9249997033718, Accuracy:
0.3624868282402529, Hit Rate: 0.48927875243664715, Trades: 513
Running iteration 10/50
30/30            1s 11ms/step
Iteration 10 - Final Portfolio Value: 88.73930608171939, Accuracy:
0.3561643835616438, Hit Rate: 0.4832, Trades: 625
Running iteration 11/50
30/30            1s 11ms/step
Iteration 11 - Final Portfolio Value: 105.99471155934351, Accuracy:
0.3129610115911486, Hit Rate: 0.5068493150684932, Trades: 949
Running iteration 12/50
30/30            1s 11ms/step
Iteration 12 - Final Portfolio Value: 95.53991829191462, Accuracy:
0.36037934668071653, Hit Rate: 0.4946401225114854, Trades: 653
Running iteration 13/50
30/30            1s 10ms/step
Iteration 13 - Final Portfolio Value: 91.52699198354529, Accuracy:
0.3403582718651212, Hit Rate: 0.4872881355932203, Trades: 708
Running iteration 14/50
30/30            1s 10ms/step
Iteration 14 - Final Portfolio Value: 89.7022256530914, Accuracy:
0.321390937829294, Hit Rate: 0.4987012987012987, Trades: 770
Running iteration 15/50
```

```
30/30            1s 11ms/step
Iteration 15 - Final Portfolio Value: 86.93463577807262, Accuracy:
0.3403582718651212, Hit Rate: 0.48142857142857143, Trades: 700
Running iteration 16/50
30/30            1s 10ms/step
Iteration 16 - Final Portfolio Value: 96.20564199093582, Accuracy:
0.3624868282402529, Hit Rate: 0.5098389982110912, Trades: 559
Running iteration 17/50
30/30            1s 10ms/step
Iteration 17 - Final Portfolio Value: 107.04639589372569, Accuracy:
0.3667017913593256, Hit Rate: 0.5, Trades: 596
Running iteration 18/50
30/30            1s 11ms/step
Iteration 18 - Final Portfolio Value: 92.62007350563819, Accuracy:
0.3561643835616438, Hit Rate: 0.4887459807073955, Trades: 622
Running iteration 19/50
30/30            1s 11ms/step
Iteration 19 - Final Portfolio Value: 88.37522488587713, Accuracy:
0.35511064278187565, Hit Rate: 0.487062404870624, Trades: 657
Running iteration 20/50
30/30            1s 10ms/step
Iteration 20 - Final Portfolio Value: 103.51816892798517, Accuracy:
0.3624868282402529, Hit Rate: 0.49920255183413076, Trades: 627
Running iteration 21/50
30/30            1s 11ms/step
Iteration 21 - Final Portfolio Value: 102.57041904147289, Accuracy:
0.3424657534246575, Hit Rate: 0.5042857142857143, Trades: 700
Running iteration 22/50
30/30            1s 10ms/step
Iteration 22 - Final Portfolio Value: 101.73830413597176, Accuracy:
0.36880927291886195, Hit Rate: 0.49768875192604006, Trades: 649
Running iteration 23/50
30/30            1s 10ms/step
Iteration 23 - Final Portfolio Value: 94.20017140719929, Accuracy:
0.33719704952581664, Hit Rate: 0.5, Trades: 732
Running iteration 24/50
30/30            1s 11ms/step
Iteration 24 - Final Portfolio Value: 102.93507249318132, Accuracy:
0.3761854583772392, Hit Rate: 0.4908616187989556, Trades: 383
Running iteration 25/50
30/30            1s 11ms/step
Iteration 25 - Final Portfolio Value: 96.20774676037958, Accuracy:
0.3656480505795574, Hit Rate: 0.4989247311827957, Trades: 465
Running iteration 26/50
30/30            1s 10ms/step
Iteration 26 - Final Portfolio Value: 93.12199692566625, Accuracy:
0.34562697576396206, Hit Rate: 0.49777777777777776, Trades: 675
Running iteration 27/50
```

```
30/30            1s 10ms/step
Iteration 27 - Final Portfolio Value: 101.9152577633143, Accuracy:
0.36880927291886195, Hit Rate: 0.496875, Trades: 640
Running iteration 28/50
30/30            1s 10ms/step
Iteration 28 - Final Portfolio Value: 102.81926319115664, Accuracy:
0.3624868282402529, Hit Rate: 0.49130434782608695, Trades: 460
Running iteration 29/50
30/30            1s 11ms/step
Iteration 29 - Final Portfolio Value: 100.5067266580977, Accuracy:
0.35721812434141204, Hit Rate: 0.497196261682243, Trades: 535
Running iteration 30/50
30/30            1s 10ms/step
Iteration 30 - Final Portfolio Value: 83.45734633154325, Accuracy:
0.3192834562697576, Hit Rate: 0.4860927152317881, Trades: 755
Running iteration 31/50
30/30            1s 10ms/step
Iteration 31 - Final Portfolio Value: 91.14026101019775, Accuracy:
0.3530031612223393, Hit Rate: 0.48861911987860396, Trades: 659
Running iteration 32/50
30/30            1s 11ms/step
Iteration 32 - Final Portfolio Value: 96.01089131334834, Accuracy:
0.3582718651211802, Hit Rate: 0.4969512195121951, Trades: 656
Running iteration 33/50
30/30            1s 11ms/step
Iteration 33 - Final Portfolio Value: 97.74509848515991, Accuracy:
0.35721812434141204, Hit Rate: 0.5022970903522205, Trades: 653
Running iteration 34/50
30/30            1s 10ms/step
Iteration 34 - Final Portfolio Value: 103.67798464143961, Accuracy:
0.37829293993677554, Hit Rate: 0.4881889763779528, Trades: 381
Running iteration 35/50
30/30            1s 10ms/step
Iteration 35 - Final Portfolio Value: 101.41947123477821, Accuracy:
0.37091675447839834, Hit Rate: 0.49912739965095987, Trades: 573
Running iteration 36/50
30/30            1s 10ms/step
Iteration 36 - Final Portfolio Value: 87.78696023555972, Accuracy:
0.3361433087460485, Hit Rate: 0.48583569405099153, Trades: 706
Running iteration 37/50
30/30            1s 10ms/step
Iteration 37 - Final Portfolio Value: 103.52439282774353, Accuracy:
0.3624868282402529, Hit Rate: 0.4982698961937716, Trades: 578
Running iteration 38/50
30/30            1s 10ms/step
Iteration 38 - Final Portfolio Value: 92.48958302499048, Accuracy:
0.3530031612223393, Hit Rate: 0.49251497005988026, Trades: 668
Running iteration 39/50
```

```
30/30            1s 11ms/step
Iteration 39 - Final Portfolio Value: 87.01775684677258, Accuracy:
0.3361433087460485, Hit Rate: 0.4876632801161103, Trades: 689
Running iteration 40/50
30/30            1s 11ms/step
Iteration 40 - Final Portfolio Value: 95.08926023845936, Accuracy:
0.3519494204425711, Hit Rate: 0.49343065693430654, Trades: 685
Running iteration 41/50
30/30            1s 10ms/step
Iteration 41 - Final Portfolio Value: 95.61748171855456, Accuracy:
0.34351949420442573, Hit Rate: 0.49697885196374625, Trades: 662
Running iteration 42/50
30/30            1s 11ms/step
Iteration 42 - Final Portfolio Value: 93.16765538247625, Accuracy:
0.3519494204425711, Hit Rate: 0.4954954954954955, Trades: 666
Running iteration 43/50
30/30            1s 11ms/step
Iteration 43 - Final Portfolio Value: 99.30866376674547, Accuracy:
0.36037934668071653, Hit Rate: 0.49725776965265084, Trades: 547
Running iteration 44/50
30/30            1s 10ms/step
Iteration 44 - Final Portfolio Value: 104.79170777917835, Accuracy:
0.36143308746048475, Hit Rate: 0.5056390977443609, Trades: 532
Running iteration 45/50
30/30            1s 10ms/step
Iteration 45 - Final Portfolio Value: 94.41960688195371, Accuracy:
0.3530031612223393, Hit Rate: 0.4970414201183432, Trades: 676
Running iteration 46/50
30/30            1s 10ms/step
Iteration 46 - Final Portfolio Value: 108.86308696317472, Accuracy:
0.36880927291886195, Hit Rate: 0.5067567567567568, Trades: 592
Running iteration 47/50
30/30            1s 11ms/step
Iteration 47 - Final Portfolio Value: 96.29912471182442, Accuracy:
0.34773445732349845, Hit Rate: 0.4979310344827586, Trades: 725
Running iteration 48/50
30/30            1s 10ms/step
Iteration 48 - Final Portfolio Value: 88.66811986909974, Accuracy:
0.29083245521601686, Hit Rate: 0.4912891986062718, Trades: 861
Running iteration 49/50
30/30            1s 10ms/step
Iteration 49 - Final Portfolio Value: 86.56536024466118, Accuracy:
0.3245521601685985, Hit Rate: 0.4879032258064516, Trades: 744
Running iteration 50/50
30/30            1s 11ms/step
Iteration 50 - Final Portfolio Value: 100.95423617241866, Accuracy:
0.37302423603793466, Hit Rate: 0.4958263772954925, Trades: 599
Average Final Portfolio Value:
```

```
96.49538054494023
Standard Deviation of Final Values:
6.1935436243472015
Average Accuracy:
0.35157007376185456
Average Hit Rate:
0.4953251519423646
Average No. of Trades:
638.82
```

6 3rd Iteration

[ ]:
```
time_steps = 15

dataX = create_dataset(dataset, time_steps)

dataX = np.reshape(dataX, (dataX.shape[0], time_steps, dataset.shape[1]))

X = dataX
y = y_categories[time_steps:]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
 ↪shuffle=False, random_state = 42)
```

[ ]:
```
def create_model_3(units1 = 128, units2 = 64,  dropout_rate1 = 0.2,␣
 ↪dropout_rate2 = 0.1, batch_size = 32, l2_value = 0.01):
    model = Sequential([
        Input(shape=(X_train.shape[1], X_train.shape[2])),
        LSTM(units1, return_sequences = True),
        Dropout(dropout_rate1),
        LSTM(units2, return_sequences = False),
        Dropout(dropout_rate2),
        Dense(3, activation = 'softmax', kernel_regularizer=l2(l2_value))
    ])
    model.compile(optimizer='adam', loss='categorical_crossentropy',␣
 ↪metrics=['accuracy'])
    return model
```

[ ]:
```
param_grid_model_3 = {
    'model__units1': [64, 128],
    'model__units2': [64, 128],
    'model__dropout_rate1': [0.2, 0.3, 0.4],
    'model__dropout_rate2': [0.2, 0.3, 0.4],
    'batch_size': [64, 128],
    'model__l2_value': [0.1, 0.01]
}
```

[ ]:
```
model_3 = KerasClassifier(model = create_model_3, epochs = 75, verbose = 0,␣
↪shuffle = False, random_state = 42)
```

[ ]:
```
grid_model_3 = GridSearchCV(estimator = model_3, param_grid =␣
↪param_grid_model_3, cv = 5, scoring = 'accuracy', n_jobs = -1)
```

[ ]:
```
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
↪start_from_epoch = 10, restore_best_weights = True)

grid_result_model_3 = grid_model_3.fit(X_train, y_train, validation_split = 0.
↪2, callbacks = [early_stopping])
```

[ ]:
```
best_params_model_3 = grid_result_model_3.best_params_

print(best_params_model_3)
```

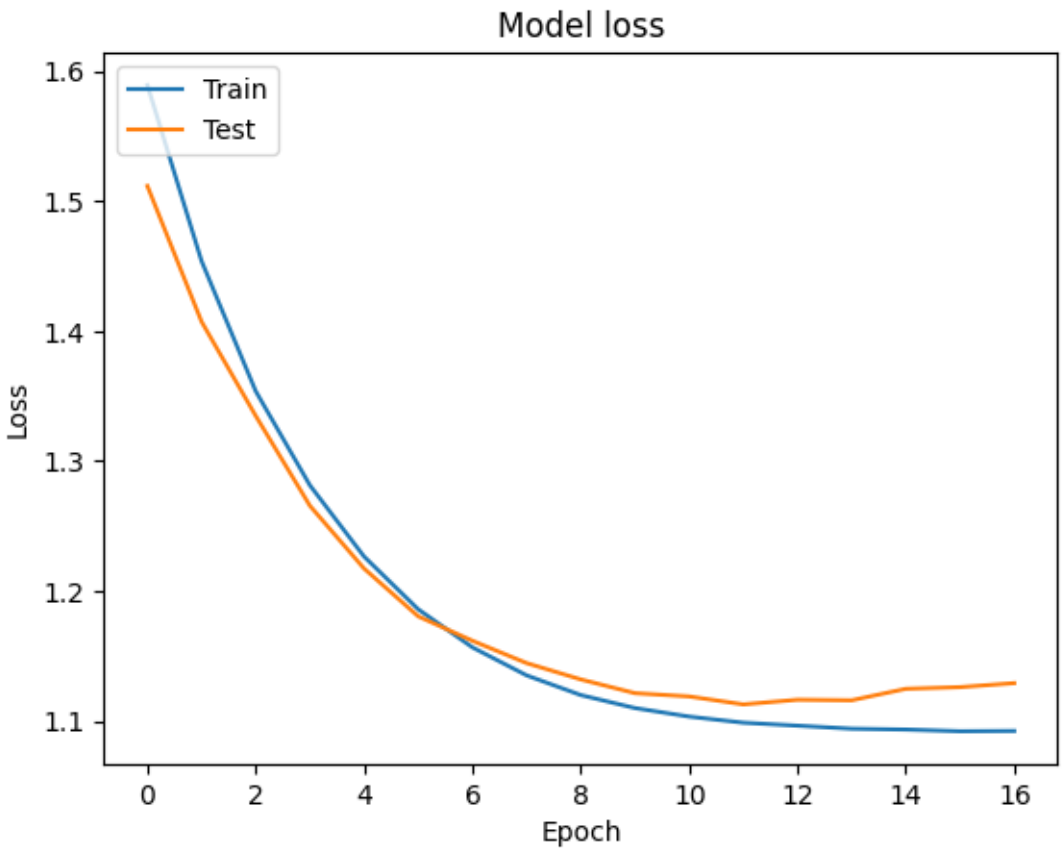
```
{'batch_size': 128, 'model__dropout_rate1': 0.4, 'model__dropout_rate2': 0.3,
'model__l2_value': 0.1, 'model__units1': 128, 'model__units2': 64}
```

[ ]:
```
best_model_3 = create_model_3(units1 = best_params_model_3['model__units1'],
                              units2 = best_params_model_3['model__units2'],
                          dropout_rate1 =␣
↪best_params_model_3['model__dropout_rate1'],
                              dropout_rate2 =␣
↪best_params_model_3['model__dropout_rate2'],
                          batch_size = best_params_model_3['batch_size'],
                              l2_value = best_params_model_3['model__l2_value']
                          )
```

[ ]:
```
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
↪start_from_epoch = 10, restore_best_weights = True)

history_model_3 = best_model_3.fit(X_train, y_train,
                         epochs = 75,
                                   batch_size = 128,
                         validation_data=(X_test, y_test),
                                   callbacks = [early_stopping],
                         verbose = 0)
```

[ ]:
```
plt.plot(history_model_3.history['loss'])
plt.plot(history_model_3.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```



[ ]:
```
y_pred = best_model_3.predict(X_test)

actual_categories = np.argmax(y_test, axis=1)

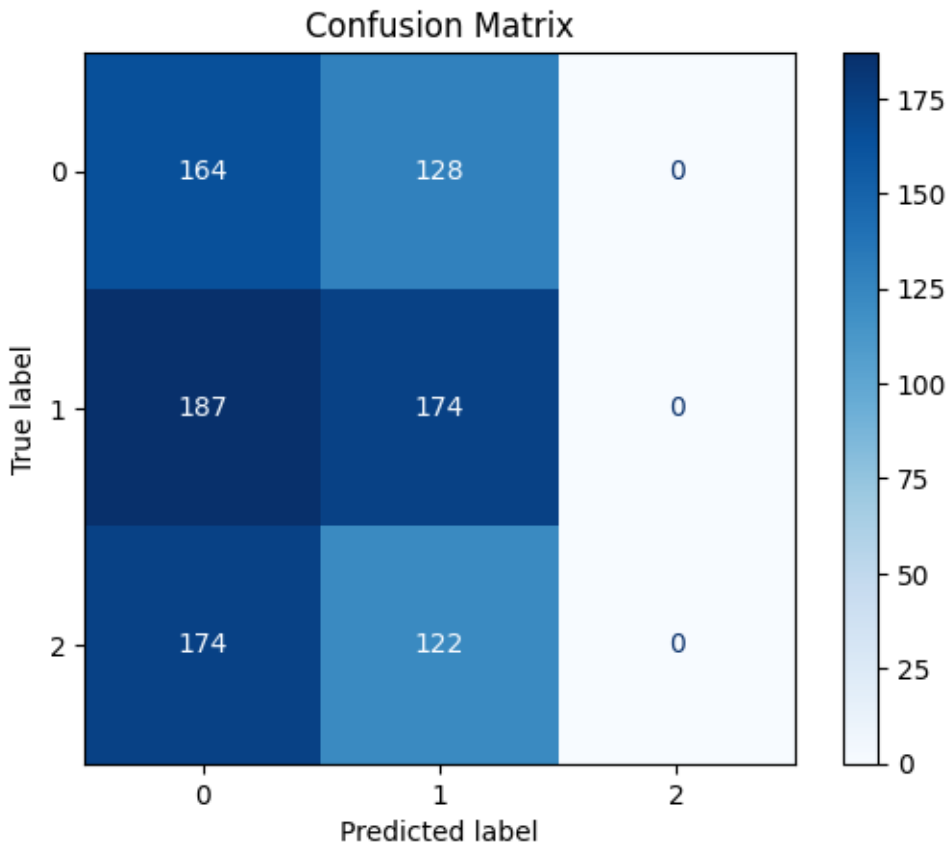
predicted_categories = np.argmax(y_pred, axis=1)

cm = confusion_matrix(actual_categories, predicted_categories)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1, 2])

plt.figure(figsize=(10, 7))
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()
```

```
30/30              0s 8ms/step
```

```
<Figure size 1000x700 with 0 Axes>
```



[ ]:
```
def compute_hit_rate(signals, percent_changes):
    correct_signals = 0
    total_signals = len(signals)

    for signal, percent_change in zip(signals, percent_changes):
        if (signal == 0 and percent_change < 0) or (signal == 2 and␣
 ↪percent_change > 0):
            correct_signals += 1
        elif signal == 1:
            total_signals -= 1

    return correct_signals / total_signals if total_signals > 0 else 0

def backtest(actions, percent_changes):
    cash = 100
    position = 0
    portfolio_value = []

    for action, percent_change in zip(actions, percent_changes):
```

```
        if action == 0:  # Sell
            position = -100  # Set position to short
            cash += position * percent_change  # Sell shares
        elif action == 1:  # Flat
            position = 0  # Set position to flat
            cash += 0  # No action
        elif action == 2:  # Buy
            position = 100  # Set position to long
            cash += position * percent_change  # Buy shares

        portfolio_value.append(cash)

    return portfolio_value

def run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_3):
    best_model_3 = create_model_3(units1 = best_params_model_3['model__units1'],
                                  units2 = best_params_model_3['model__units2'],
                              dropout_rate1 =␣
 ↪best_params_model_3['model__dropout_rate1'],
                                  dropout_rate2 =␣
 ↪best_params_model_3['model__dropout_rate2'],
                              batch_size = best_params_model_3['batch_size'],
                                     l2_value =␣
 ↪best_params_model_3['model__l2_value']
                              )

    early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
 ↪start_from_epoch = 10, restore_best_weights = True)

    history_model_3 = best_model_3.fit(X_train, y_train,
                          epochs = 75,
                                   batch_size = 128,
                          validation_data = (X_test, y_test),
                                   callbacks = [early_stopping],
                          verbose = 0)

    predictions = best_model_3.predict(X_test)
    predicted_categories = np.argmax(predictions, axis=1)

    y_test_labels = np.argmax(y_test, axis=1)

    accuracy = accuracy_score(y_test_labels, predicted_categories)

    signals = predicted_categories
    percent_changes = np.array(df_raw_exchange.iloc[-len(y_test):])

    portfolio_value = backtest(signals, percent_changes)
```

```
    hit_rate = compute_hit_rate(signals, percent_changes)
    num_trades = np.sum((signals == 0) | (signals == 2))


    return portfolio_value, accuracy, hit_rate, num_trades

iterations = 50

final_portfolio_values = []
accuracies = []
hit_rates = []
trade_counts = []

for i in range(iterations):
    print(f"Running iteration {i+1}/{iterations}")
    portfolio_value, accuracy, hit_rate, num_trades =␣
 ↪run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_3)
    final_portfolio_values.append(portfolio_value[-1])
    accuracies.append(accuracy)
    hit_rates.append(hit_rate)
    trade_counts.append(num_trades)
    print(f"Iteration {i+1} - Final Portfolio Value: {portfolio_value[-1]},␣
 ↪Accuracy: {accuracy}, Hit Rate: {hit_rate}, Trades: {num_trades}")

average_final_value = np.mean(final_portfolio_values)
std_final_value = np.std(final_portfolio_values)

average_accuracy = np.mean(accuracies)
average_hit_rate = np.mean(hit_rates)
average_num_trades = np.mean(trade_counts)

print("Average Final Portfolio Value:")
print(average_final_value)
print('Standard Deviation of Final Values:')
print(std_final_value)
print('Average Accuracy:')
print(average_accuracy)
print('Average Hit Rate:')
print(average_hit_rate)
print('Average No. of Trades:')
print(average_num_trades)
```

```
Running iteration 1/100
30/30             0s 8ms/step
Iteration 1 - Final Portfolio Value: 98.38139270693449, Accuracy:
0.35721812434141204, Hit Rate: 0.5056179775280899, Trades: 534
Running iteration 2/100
```

```
30/30             0s 8ms/step
Iteration 2 - Final Portfolio Value: 100.34972953844746, Accuracy:
0.36143308746048475, Hit Rate: 0.5110220440881763, Trades: 499
Running iteration 3/100
30/30             0s 8ms/step
Iteration 3 - Final Portfolio Value: 99.72011345258545, Accuracy:
0.36880927291886195, Hit Rate: 0.5028790786948176, Trades: 521
Running iteration 4/100
30/30             0s 8ms/step
Iteration 4 - Final Portfolio Value: 93.57447078992806, Accuracy:
0.36459430979978924, Hit Rate: 0.49361702127659574, Trades: 470
Running iteration 5/100
30/30             0s 8ms/step
Iteration 5 - Final Portfolio Value: 105.13685886060284, Accuracy:
0.36880927291886195, Hit Rate: 0.5093945720250522, Trades: 479
Running iteration 6/100
30/30             0s 8ms/step
Iteration 6 - Final Portfolio Value: 102.974662302947, Accuracy:
0.36880927291886195, Hit Rate: 0.50920245398773, Trades: 489
Running iteration 7/100
30/30             0s 8ms/step
Iteration 7 - Final Portfolio Value: 99.67116555495255, Accuracy:
0.3656480505795574, Hit Rate: 0.4869402985074627, Trades: 536
Running iteration 8/100
30/30             1s 23ms/step
Iteration 8 - Final Portfolio Value: 103.87018680470905, Accuracy:
0.3677555321390938, Hit Rate: 0.5079365079365079, Trades: 504
Running iteration 9/100
30/30             0s 8ms/step
Iteration 9 - Final Portfolio Value: 96.80799445452924, Accuracy:
0.3656480505795574, Hit Rate: 0.49043478260869566, Trades: 575
Running iteration 10/100
30/30             0s 8ms/step
Iteration 10 - Final Portfolio Value: 91.76672500236711, Accuracy:
0.35511064278187565, Hit Rate: 0.48973143759873616, Trades: 633
Running iteration 11/100
30/30             0s 8ms/step
Iteration 11 - Final Portfolio Value: 93.75445731962536, Accuracy:
0.3540569020021075, Hit Rate: 0.4929078014184397, Trades: 564
Running iteration 12/100
30/30             0s 8ms/step
Iteration 12 - Final Portfolio Value: 110.78435684991598, Accuracy:
0.3772391991570074, Hit Rate: 0.5174603174603175, Trades: 630
Running iteration 13/100
30/30             0s 8ms/step
Iteration 13 - Final Portfolio Value: 102.91633005673461, Accuracy:
0.36037934668071653, Hit Rate: 0.49335863377609107, Trades: 527
Running iteration 14/100
```

```
30/30             0s 8ms/step
Iteration 14 - Final Portfolio Value: 100.45362358760804, Accuracy:
0.3677555321390938, Hit Rate: 0.49559082892416223, Trades: 567
Running iteration 15/100
30/30             0s 7ms/step
Iteration 15 - Final Portfolio Value: 108.8444478926651, Accuracy:
0.3719704952581665, Hit Rate: 0.511326860841424, Trades: 618
Running iteration 16/100
30/30             0s 8ms/step
Iteration 16 - Final Portfolio Value: 97.74062037319243, Accuracy:
0.36880927291886195, Hit Rate: 0.506198347107438, Trades: 484
Running iteration 17/100
30/30             0s 8ms/step
Iteration 17 - Final Portfolio Value: 103.94829747019214, Accuracy:
0.3635405690200211, Hit Rate: 0.5051020408163265, Trades: 588
Running iteration 18/100
30/30             0s 8ms/step
Iteration 18 - Final Portfolio Value: 101.67436546262313, Accuracy:
0.3624868282402529, Hit Rate: 0.5067961165048543, Trades: 515
Running iteration 19/100
30/30             0s 8ms/step
Iteration 19 - Final Portfolio Value: 89.07903281151067, Accuracy:
0.3224446786090622, Hit Rate: 0.49171974522292994, Trades: 785
Running iteration 20/100
30/30             0s 8ms/step
Iteration 20 - Final Portfolio Value: 102.29503903692944, Accuracy:
0.35511064278187565, Hit Rate: 0.5150214592274678, Trades: 699
Running iteration 21/100
30/30             0s 8ms/step
Iteration 21 - Final Portfolio Value: 103.4485565069525, Accuracy:
0.3540569020021075, Hit Rate: 0.5154185022026432, Trades: 681
Running iteration 22/100
30/30             0s 8ms/step
Iteration 22 - Final Portfolio Value: 96.01573493332306, Accuracy:
0.36143308746048475, Hit Rate: 0.4984520123839009, Trades: 646
Running iteration 23/100
30/30             0s 8ms/step
Iteration 23 - Final Portfolio Value: 104.31309609266282, Accuracy:
0.3698630136986301, Hit Rate: 0.4981684981684982, Trades: 546
Running iteration 24/100
30/30             0s 8ms/step
Iteration 24 - Final Portfolio Value: 101.57275649568396, Accuracy:
0.36459430979978924, Hit Rate: 0.5128712871287129, Trades: 505
Running iteration 25/100
30/30             0s 7ms/step
Iteration 25 - Final Portfolio Value: 102.61561199156091, Accuracy:
0.36037934668071653, Hit Rate: 0.5058823529411764, Trades: 510
Running iteration 26/100
```

```
30/30             0s 8ms/step
Iteration 26 - Final Portfolio Value: 97.57119485866826, Accuracy:
0.3582718651211802, Hit Rate: 0.501937984496124, Trades: 516
Running iteration 27/100
30/30             0s 7ms/step
Iteration 27 - Final Portfolio Value: 105.37891659712153, Accuracy:
0.37302423603793466, Hit Rate: 0.5024793388429752, Trades: 605
Running iteration 28/100
30/30             0s 8ms/step
Iteration 28 - Final Portfolio Value: 107.01646490445123, Accuracy:
0.37513171759747105, Hit Rate: 0.5017064846416383, Trades: 586
Running iteration 29/100
30/30             0s 8ms/step
Iteration 29 - Final Portfolio Value: 106.08729469682186, Accuracy:
0.37302423603793466, Hit Rate: 0.5224171539961013, Trades: 513
Running iteration 30/100
30/30             0s 7ms/step
Iteration 30 - Final Portfolio Value: 99.16431655917168, Accuracy:
0.3624868282402529, Hit Rate: 0.5027522935779817, Trades: 545
Running iteration 31/100
30/30             0s 8ms/step
Iteration 31 - Final Portfolio Value: 108.84917342036101, Accuracy:
0.3667017913593256, Hit Rate: 0.512539184952978, Trades: 638
Running iteration 32/100
30/30             0s 8ms/step
Iteration 32 - Final Portfolio Value: 96.8362986280637, Accuracy:
0.35932560590094836, Hit Rate: 0.4990512333965844, Trades: 527
Running iteration 33/100
30/30             0s 8ms/step
Iteration 33 - Final Portfolio Value: 96.02714537445526, Accuracy:
0.35932560590094836, Hit Rate: 0.49407114624505927, Trades: 506
Running iteration 34/100
30/30             0s 8ms/step
Iteration 34 - Final Portfolio Value: 109.27728344823952, Accuracy:
0.3635405690200211, Hit Rate: 0.5207715133531158, Trades: 674
Running iteration 35/100
30/30             0s 8ms/step
Iteration 35 - Final Portfolio Value: 100.67988694261228, Accuracy:
0.3635405690200211, Hit Rate: 0.4936440677966102, Trades: 472
Running iteration 36/100
30/30             0s 8ms/step
Iteration 36 - Final Portfolio Value: 102.05271960486795, Accuracy:
0.36143308746048475, Hit Rate: 0.5, Trades: 480
Running iteration 37/100
30/30             0s 8ms/step
Iteration 37 - Final Portfolio Value: 102.93621116125311, Accuracy:
0.3719704952581665, Hit Rate: 0.5065176908752328, Trades: 537
Running iteration 38/100
```

```
30/30             0s 8ms/step
Iteration 38 - Final Portfolio Value: 105.95151406688848, Accuracy:
0.3698630136986301, Hit Rate: 0.5098389982110912, Trades: 559
Running iteration 39/100
30/30             0s 8ms/step
Iteration 39 - Final Portfolio Value: 102.59641231630113, Accuracy:
0.36880927291886195, Hit Rate: 0.49409780775716694, Trades: 593
Running iteration 40/100
30/30             0s 8ms/step
Iteration 40 - Final Portfolio Value: 95.92408277807104, Accuracy:
0.3582718651211802, Hit Rate: 0.488245931283906, Trades: 553
Running iteration 41/100
30/30             0s 7ms/step
Iteration 41 - Final Portfolio Value: 93.62140443109332, Accuracy:
0.35932560590094836, Hit Rate: 0.49498997995991983, Trades: 499
Running iteration 42/100
30/30             0s 8ms/step
Iteration 42 - Final Portfolio Value: 96.26888729885536, Accuracy:
0.3129610115911486, Hit Rate: 0.5035885167464115, Trades: 836
Running iteration 43/100
30/30             0s 8ms/step
Iteration 43 - Final Portfolio Value: 102.87177086610092, Accuracy:
0.3656480505795574, Hit Rate: 0.5038461538461538, Trades: 520
Running iteration 44/100
30/30             0s 7ms/step
Iteration 44 - Final Portfolio Value: 87.65673578635526, Accuracy:
0.3129610115911486, Hit Rate: 0.49313358302122345, Trades: 801
Running iteration 45/100
30/30             0s 7ms/step
Iteration 45 - Final Portfolio Value: 104.43391115928074, Accuracy:
0.3656480505795574, Hit Rate: 0.49755301794453505, Trades: 613
Running iteration 46/100
30/30             0s 7ms/step
Iteration 46 - Final Portfolio Value: 101.24793605319601, Accuracy:
0.3677555321390938, Hit Rate: 0.508130081300813, Trades: 492
Running iteration 47/100
30/30             0s 7ms/step
Iteration 47 - Final Portfolio Value: 107.76896364380015, Accuracy:
0.36459430979978924, Hit Rate: 0.5081699346405228, Trades: 612
Running iteration 48/100
30/30             0s 8ms/step
Iteration 48 - Final Portfolio Value: 95.60538010017194, Accuracy:
0.35511064278187565, Hit Rate: 0.4897579143389199, Trades: 537
Running iteration 49/100
30/30             0s 7ms/step
Iteration 49 - Final Portfolio Value: 102.55580473727346, Accuracy:
0.36037934668071653, Hit Rate: 0.49818181818181817, Trades: 550
Running iteration 50/100
```

```
30/30             0s 8ms/step
Iteration 50 - Final Portfolio Value: 89.68860872810163, Accuracy:
0.3013698630136986, Hit Rate: 0.4939613526570048, Trades: 828
Running iteration 51/100
30/30             0s 8ms/step
Iteration 51 - Final Portfolio Value: 97.86854095970418, Accuracy:
0.36459430979978924, Hit Rate: 0.5207100591715976, Trades: 507
Running iteration 52/100
30/30             0s 8ms/step
Iteration 52 - Final Portfolio Value: 99.09681118797296, Accuracy:
0.3582718651211802, Hit Rate: 0.501953125, Trades: 512
Running iteration 53/100
30/30             0s 8ms/step
Iteration 53 - Final Portfolio Value: 101.27949992548527, Accuracy:
0.3656480505795574, Hit Rate: 0.5031446540880503, Trades: 477
Running iteration 54/100
30/30             0s 8ms/step
Iteration 54 - Final Portfolio Value: 101.28642869161098, Accuracy:
0.36459430979978924, Hit Rate: 0.49504950495049505, Trades: 505
Running iteration 55/100
30/30             0s 8ms/step
Iteration 55 - Final Portfolio Value: 100.00553969635737, Accuracy:
0.36037934668071653, Hit Rate: 0.5080645161290323, Trades: 496
Running iteration 56/100
30/30             0s 8ms/step
Iteration 56 - Final Portfolio Value: 102.45873877842075, Accuracy:
0.3656480505795574, Hit Rate: 0.4971209213051823, Trades: 521
Running iteration 57/100
30/30             0s 8ms/step
Iteration 57 - Final Portfolio Value: 94.45405692085332, Accuracy:
0.3540569020021075, Hit Rate: 0.49295774647887325, Trades: 568
Running iteration 58/100
30/30             0s 8ms/step
Iteration 58 - Final Portfolio Value: 94.33349764220469, Accuracy:
0.32982086406743943, Hit Rate: 0.49523809523809526, Trades: 735
Running iteration 59/100
30/30             0s 8ms/step
Iteration 59 - Final Portfolio Value: 102.88039419469314, Accuracy:
0.36880927291886195, Hit Rate: 0.5022222222222222, Trades: 450
Running iteration 60/100
30/30             0s 8ms/step
Iteration 60 - Final Portfolio Value: 106.88638757085548, Accuracy:
0.37302423603793466, Hit Rate: 0.514344262295082, Trades: 488
Running iteration 61/100
30/30             0s 8ms/step
Iteration 61 - Final Portfolio Value: 93.97334657431429, Accuracy:
0.3656480505795574, Hit Rate: 0.49673202614379086, Trades: 459
Running iteration 62/100
```

```
30/30             0s 8ms/step
Iteration 62 - Final Portfolio Value: 102.81992947130092, Accuracy:
0.36880927291886195, Hit Rate: 0.4944, Trades: 625
Running iteration 63/100
30/30             0s 8ms/step
Iteration 63 - Final Portfolio Value: 100.77868445326814, Accuracy:
0.36143308746048475, Hit Rate: 0.5093945720250522, Trades: 479
Running iteration 64/100
30/30             0s 8ms/step
Iteration 64 - Final Portfolio Value: 102.52145711352613, Accuracy:
0.3624868282402529, Hit Rate: 0.5048169556840078, Trades: 519
Running iteration 65/100
30/30             0s 8ms/step
Iteration 65 - Final Portfolio Value: 104.56994220529243, Accuracy:
0.3624868282402529, Hit Rate: 0.499054820415879, Trades: 529
Running iteration 66/100
30/30             0s 7ms/step
Iteration 66 - Final Portfolio Value: 99.09335009604382, Accuracy:
0.36143308746048475, Hit Rate: 0.5028462998102466, Trades: 527
Running iteration 67/100
30/30             0s 8ms/step
Iteration 67 - Final Portfolio Value: 97.49407247033538, Accuracy:
0.2992623814541623, Hit Rate: 0.501123595505618, Trades: 890
Running iteration 68/100
30/30             0s 9ms/step
Iteration 68 - Final Portfolio Value: 99.95805122701282, Accuracy:
0.36459430979978924, Hit Rate: 0.4894067796610169, Trades: 472
Running iteration 69/100
30/30             0s 8ms/step
Iteration 69 - Final Portfolio Value: 101.42315997749351, Accuracy:
0.35932560590094836, Hit Rate: 0.5057471264367817, Trades: 522
Running iteration 70/100
30/30             0s 9ms/step
Iteration 70 - Final Portfolio Value: 98.82344961448501, Accuracy:
0.3498419388830348, Hit Rate: 0.4972972972972973, Trades: 555
Running iteration 71/100
30/30             0s 8ms/step
Iteration 71 - Final Portfolio Value: 109.74194372689857, Accuracy:
0.36037934668071653, Hit Rate: 0.5119266055045871, Trades: 545
Running iteration 72/100
30/30             0s 8ms/step
Iteration 72 - Final Portfolio Value: 98.4421078541038, Accuracy:
0.3530031612223393, Hit Rate: 0.4965635738831615, Trades: 582
Running iteration 73/100
30/30             0s 9ms/step
Iteration 73 - Final Portfolio Value: 99.34508270999342, Accuracy:
0.35511064278187565, Hit Rate: 0.4981132075471698, Trades: 530
Running iteration 74/100
```

```
30/30             0s 8ms/step
Iteration 74 - Final Portfolio Value: 107.54023654924455, Accuracy:
0.36037934668071653, Hit Rate: 0.5112359550561798, Trades: 534
Running iteration 75/100
30/30             0s 8ms/step
Iteration 75 - Final Portfolio Value: 109.51883581430215, Accuracy:
0.3624868282402529, Hit Rate: 0.5095419847328244, Trades: 524
Running iteration 76/100
30/30             0s 8ms/step
Iteration 76 - Final Portfolio Value: 96.51114971922169, Accuracy:
0.36037934668071653, Hit Rate: 0.5032679738562091, Trades: 459
Running iteration 77/100
30/30             0s 8ms/step
Iteration 77 - Final Portfolio Value: 100.50707031343934, Accuracy:
0.36037934668071653, Hit Rate: 0.5, Trades: 514
Running iteration 78/100
30/30             0s 8ms/step
Iteration 78 - Final Portfolio Value: 99.39044520741902, Accuracy:
0.35511064278187565, Hit Rate: 0.5139146567717996, Trades: 539
Running iteration 79/100
30/30             0s 8ms/step
Iteration 79 - Final Portfolio Value: 107.2203572063276, Accuracy:
0.3719704952581665, Hit Rate: 0.5081374321880651, Trades: 553
Running iteration 80/100
30/30             0s 8ms/step
Iteration 80 - Final Portfolio Value: 106.65793012920062, Accuracy:
0.3624868282402529, Hit Rate: 0.5170340681362725, Trades: 499
Running iteration 81/100
30/30             0s 8ms/step
Iteration 81 - Final Portfolio Value: 93.77601029119101, Accuracy:
0.2950474183350896, Hit Rate: 0.492152466367713, Trades: 892
Running iteration 82/100
30/30             0s 8ms/step
Iteration 82 - Final Portfolio Value: 101.01115957483964, Accuracy:
0.35511064278187565, Hit Rate: 0.48741007194244607, Trades: 556
Running iteration 83/100
30/30             0s 8ms/step
Iteration 83 - Final Portfolio Value: 97.39331135596976, Accuracy:
0.3635405690200211, Hit Rate: 0.49498997995991983, Trades: 499
Running iteration 84/100
30/30             0s 8ms/step
Iteration 84 - Final Portfolio Value: 100.30760725850904, Accuracy:
0.3635405690200211, Hit Rate: 0.49793388429752067, Trades: 484
Running iteration 85/100
30/30             0s 8ms/step
Iteration 85 - Final Portfolio Value: 100.75525505607187, Accuracy:
0.37407797681770283, Hit Rate: 0.48903508771929827, Trades: 456
Running iteration 86/100
```

```
30/30             0s 8ms/step
Iteration 86 - Final Portfolio Value: 95.3879255214483, Accuracy:
0.36880927291886195, Hit Rate: 0.5, Trades: 548
Running iteration 87/100
30/30             0s 8ms/step
Iteration 87 - Final Portfolio Value: 102.79370262735506, Accuracy:
0.3667017913593256, Hit Rate: 0.5045207956600362, Trades: 553
Running iteration 88/100
30/30             0s 8ms/step
Iteration 88 - Final Portfolio Value: 101.09085708491705, Accuracy:
0.3582718651211802, Hit Rate: 0.4984126984126984, Trades: 630
Running iteration 89/100
30/30             0s 8ms/step
Iteration 89 - Final Portfolio Value: 101.49604501259603, Accuracy:
0.3635405690200211, Hit Rate: 0.4793388429752066, Trades: 484
Running iteration 90/100
30/30             0s 8ms/step
Iteration 90 - Final Portfolio Value: 99.75196018376583, Accuracy:
0.3635405690200211, Hit Rate: 0.5142857142857142, Trades: 490
Running iteration 91/100
30/30             0s 8ms/step
Iteration 91 - Final Portfolio Value: 81.81354094277256, Accuracy:
0.29083245521601686, Hit Rate: 0.4843205574912892, Trades: 861
Running iteration 92/100
30/30             0s 8ms/step
Iteration 92 - Final Portfolio Value: 97.85437032797603, Accuracy:
0.3719704952581665, Hit Rate: 0.49183303085299457, Trades: 551
Running iteration 93/100
30/30             0s 8ms/step
Iteration 93 - Final Portfolio Value: 98.27139788436418, Accuracy:
0.36143308746048475, Hit Rate: 0.5040816326530613, Trades: 490
Running iteration 94/100
30/30             0s 8ms/step
Iteration 94 - Final Portfolio Value: 96.34855305027037, Accuracy:
0.3540569020021075, Hit Rate: 0.5, Trades: 556
Running iteration 95/100
30/30             0s 8ms/step
Iteration 95 - Final Portfolio Value: 99.83819254559086, Accuracy:
0.3635405690200211, Hit Rate: 0.5212355212355212, Trades: 518
Running iteration 96/100
30/30             0s 8ms/step
Iteration 96 - Final Portfolio Value: 101.01964545214773, Accuracy:
0.3582718651211802, Hit Rate: 0.5, Trades: 528
Running iteration 97/100
30/30             0s 8ms/step
Iteration 97 - Final Portfolio Value: 112.84307520787502, Accuracy:
0.3698630136986301, Hit Rate: 0.5122349102773246, Trades: 613
Running iteration 98/100
```

```
30/30             0s 8ms/step
Iteration 98 - Final Portfolio Value: 102.384600281148, Accuracy:
0.36459430979978924, Hit Rate: 0.5086887835703001, Trades: 633
Running iteration 99/100
30/30             0s 8ms/step
Iteration 99 - Final Portfolio Value: 111.08938592826215, Accuracy:
0.37091675447839834, Hit Rate: 0.5159474671669794, Trades: 533
Running iteration 100/100
30/30             0s 8ms/step
Iteration 100 - Final Portfolio Value: 97.01743566831657, Accuracy:
0.35721812434141204, Hit Rate: 0.4878048780487805, Trades: 492
Average Final Portfolio Value:
100.58902473767529
Standard Deviation of Final Values:
5.198183792670207
Average Accuracy:
0.35905163329820866
Average Hit Rate:
0.5020002052089152
Average No. of Trades:
561.79
```

7 4th Iteration

[ ]:
```
file_path = '/content/final_dataset_iteration2.csv'
df = pd.read_csv(file_path)

dataset = df.values[:, 0:].astype('float64')

diff = dataset[:,0:1]
```

[ ]:
```
# 34.1 quantile: -0.0021999999999999
# 65 quantile:  0.0021999999999999

def categorize_diff(diff):
    if diff < -0.0021999999999999:
        return 0  # Price fall bucket
    elif diff > 0.0021999999999999:
        return 2  # Price rise bucket
    else:
        return 1  # Price no cation bucket

y_categories = np.array([categorize_diff(pc) for pc in diff])
```

[ ]:
```
y_categories = to_categorical(y_categories)

scaler = MinMaxScaler(feature_range=(0, 1))
```

```
dataset = scaler.fit_transform(dataset[:, 1:])
```

[ ]:
```
def create_dataset(dataset, time_steps = 1):
    dataX = []
    for i in range(len(dataset) - time_steps):
        a = dataset[i:(i + time_steps), :]
        dataX.append(a)
    return np.array(dataX)
```

[ ]:
```
time_steps = 15

dataX = create_dataset(dataset, time_steps)

dataX = np.reshape(dataX, (dataX.shape[0], time_steps, dataset.shape[1]))

X = dataX
y = y_categories[time_steps:]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2,␣
 ↪shuffle = False)
```

[ ]:
```
def create_model_4(units1 = 128, dropout_rate1 = 0.3, batch_size = 32):
    model = Sequential([
        Input(shape = (X_train.shape[1], X_train.shape[2])),
        LSTM(units1, return_sequences = False),
        Dropout(dropout_rate1),
        Dense(3, activation = 'softmax')
    ])
    model.compile(optimizer = 'adam', loss = 'categorical_crossentropy',␣
 ↪metrics = ['accuracy'])
    return model
```

[ ]:
```
model_4 = KerasClassifier(model = create_model_4, epochs = 75, verbose = 0,␣
 ↪shuffle = False, random_state = 42)
```

[ ]:
```
param_grid_model4 = {
    'model__units1': [32, 64, 128],
    'model__dropout_rate1': [0.4, 0.3, 0.2],
    'batch_size': [32, 64, 128],
}
```

[ ]:
```
grid_model_4 = GridSearchCV(estimator = model_4, param_grid =␣
 ↪param_grid_model4, cv = 5, n_jobs = -1)
```

[ ]:
```
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
 ↪start_from_epoch = 10, restore_best_weights = True)
```

```
grid_result_model_4 = grid_model_4.fit(X_train, y_train, validation_split = 0.
↪2, callbacks = [early_stopping])
```

[ ]:
```
best_params_model_4 = grid_result_model_4.best_params_

print(best_params_model_4)
```

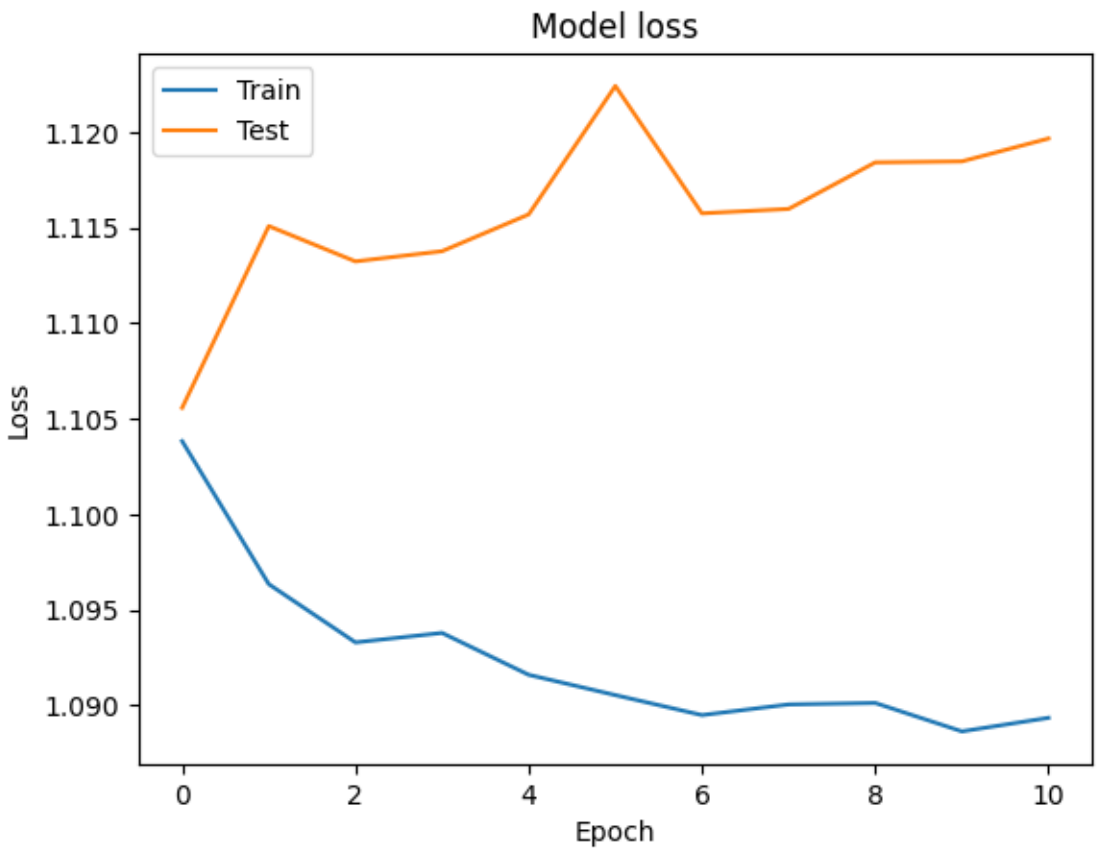
```
{'batch_size': 32, 'model__dropout_rate1': 0.4, 'model__units1': 32}
```

[ ]:
```
best_model_4 = create_model_4(units1 = best_params_model_4['model__units1'],
                              dropout_rate1 =␣
↪best_params_model_4['model__dropout_rate1'],
                              batch_size = best_params_model_4['batch_size']
                              )
```

[ ]:
```
early_stopping_manual = EarlyStopping(monitor = 'val_loss', patience = 10,␣
↪restore_best_weights = True)

history_model_4 = best_model_4.fit(X_train, y_train,
                            epochs = 75,
                            validation_data = (X_test, y_test),
                                      batch_size = 32, # remember to change␣
↪(default 32).
                           callbacks = [early_stopping_manual],
                            verbose = 0)
```

[ ]:
```
plt.plot(history_model_4.history['loss'])
plt.plot(history_model_4.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```



[ ]:
```
y_pred = best_model_4.predict(X_test)

actual_categories = np.argmax(y_test, axis=1)

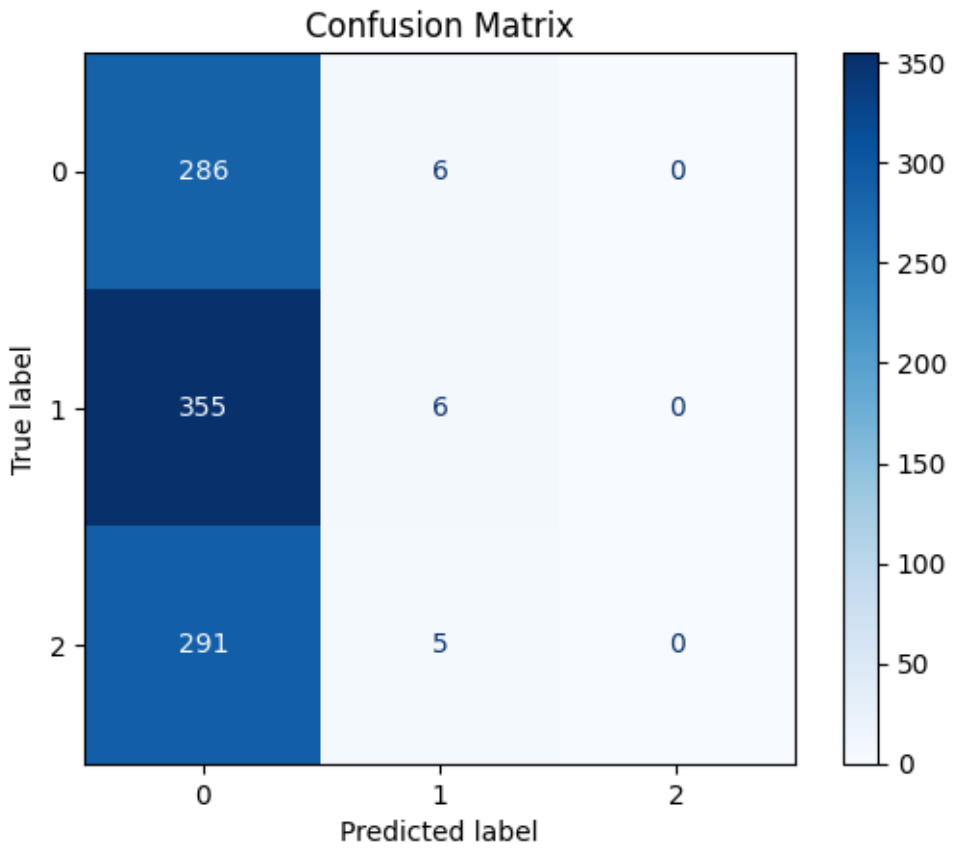
predicted_categories = np.argmax(y_pred, axis=1)

cm = confusion_matrix(actual_categories, predicted_categories)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1, 2])

plt.figure(figsize=(10, 7))
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()
```

```
30/30              0s 6ms/step
```

```
<Figure size 1000x700 with 0 Axes>
```



[ ]:
```
def compute_hit_rate(signals, percent_changes):
    correct_signals = 0
    total_signals = len(signals)

    for signal, percent_change in zip(signals, percent_changes):
        if (signal == 0 and percent_change < 0) or (signal == 2 and␣
 ↪percent_change > 0):
            correct_signals += 1
        elif signal == 1:
            total_signals -= 1

    return correct_signals / total_signals if total_signals > 0 else 0

def backtest(actions, percent_changes):
    cash = 100
    position = 0
    portfolio_value = []

    for action, percent_change in zip(actions, percent_changes):
```

```
        if action == 0:  # Sell
            position = -100  # Set position to short
            cash += position * percent_change  # Sell shares
        elif action == 1:  # Flat
            position = 0  # Set position to flat
            cash += 0  # No action
        elif action == 2:  # Buy
            position = 100  # Set position to long
            cash += position * percent_change  # Buy shares

        portfolio_value.append(cash)

    return portfolio_value

def run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_4):
    best_model_4 = create_model_4(units1 = best_params_model_4['model__units1'],
                           dropout_rate1 =␣
 ↪best_params_model_4['model__dropout_rate1'],
                           batch_size = best_params_model_4['batch_size']
                           )

    early_stopping_manual = EarlyStopping(monitor='val_loss', patience = 10,␣
 ↪restore_best_weights = True)

    history_model_4 = best_model_4.fit(X_train, y_train,
                          epochs = 100,
                          validation_data = (X_test, y_test),
                                    batch_size = 32, # remember to change␣
 ↪(default 32).
                         callbacks = [early_stopping_manual],
                          verbose = 0)

    predictions = best_model_4.predict(X_test)
    predicted_categories = np.argmax(predictions, axis=1)

    y_test_labels = np.argmax(y_test, axis=1)

    accuracy = accuracy_score(y_test_labels, predicted_categories)

    signals = predicted_categories
    percent_changes = np.array(df_raw_exchange.iloc[-len(y_test):])

    portfolio_value = backtest(signals, percent_changes)
    hit_rate = compute_hit_rate(signals, percent_changes)
    num_trades = np.sum((signals == 0) | (signals == 2))
```

```
    return portfolio_value, accuracy, hit_rate, num_trades

iterations = 50

final_portfolio_values = []
accuracies = []
hit_rates = []
trade_counts = []

for i in range(iterations):
    print(f"Running iteration {i+1}/{iterations}")
    portfolio_value, accuracy, hit_rate, num_trades =␣
 ↪run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_4)
    final_portfolio_values.append(portfolio_value[-1])
    accuracies.append(accuracy)
    hit_rates.append(hit_rate)
    trade_counts.append(num_trades)
    print(f"Iteration {i+1} - Final Portfolio Value: {portfolio_value[-1]},␣
 ↪Accuracy: {accuracy}, Hit Rate: {hit_rate}, Trades: {num_trades}")

average_final_value = np.mean(final_portfolio_values)
std_final_value = np.std(final_portfolio_values)

average_accuracy = np.mean(accuracies)
average_hit_rate = np.mean(hit_rates)
average_num_trades = np.mean(trade_counts)

print("Average Final Portfolio Value:")
print(average_final_value)
print('Standard Deviation of Final Values:')
print(std_final_value)
print('Average Accuracy:')
print(average_accuracy)
print('Average Hit Rate:')
print(average_hit_rate)
print('Average No. of Trades:')
print(average_num_trades)
```

```
Running iteration 1/50
30/30             0s 5ms/step
Iteration 1 - Final Portfolio Value: 96.34521046177825, Accuracy:
0.3076923076923077, Hit Rate: 0.5026343519494204, Trades: 949
Running iteration 2/50
30/30             0s 5ms/step
Iteration 2 - Final Portfolio Value: 93.81178843289874, Accuracy:
0.3087460484720759, Hit Rate: 0.500542888165038, Trades: 921
Running iteration 3/50
```

```
30/30             0s 5ms/step
Iteration 3 - Final Portfolio Value: 113.68251708537395, Accuracy:
0.33719704952581664, Hit Rate: 0.5061728395061729, Trades: 810
Running iteration 4/50
30/30             0s 5ms/step
Iteration 4 - Final Portfolio Value: 95.88213986443522, Accuracy:
0.3055848261327713, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 5/50
30/30             0s 5ms/step
Iteration 5 - Final Portfolio Value: 94.79579964625644, Accuracy:
0.30242360379346683, Hit Rate: 0.48788198103266595, Trades: 949
Running iteration 6/50
30/30             0s 5ms/step
Iteration 6 - Final Portfolio Value: 100.35987434294468, Accuracy:
0.3108535300316122, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 7/50
30/30             0s 5ms/step
Iteration 7 - Final Portfolio Value: 106.49262342813226, Accuracy:
0.31822971548998946, Hit Rate: 0.5105708245243129, Trades: 946
Running iteration 8/50
30/30             0s 5ms/step
Iteration 8 - Final Portfolio Value: 97.20289454686824, Accuracy:
0.30453108535300316, Hit Rate: 0.48824188129899215, Trades: 893
Running iteration 9/50
30/30             0s 5ms/step
Iteration 9 - Final Portfolio Value: 99.0169484989736, Accuracy:
0.3076923076923077, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 10/50
30/30             0s 5ms/step
Iteration 10 - Final Portfolio Value: 101.03745143348537, Accuracy:
0.3066385669125395, Hit Rate: 0.4910432033719705, Trades: 949
Running iteration 11/50
30/30             0s 5ms/step
Iteration 11 - Final Portfolio Value: 96.11761657426324, Accuracy:
0.3076923076923077, Hit Rate: 0.5036880927291886, Trades: 949
Running iteration 12/50
30/30             0s 5ms/step
Iteration 12 - Final Portfolio Value: 110.80113962189158, Accuracy:
0.3224446786090622, Hit Rate: 0.5111111111111111, Trades: 945
Running iteration 13/50
30/30             0s 5ms/step
Iteration 13 - Final Portfolio Value: 91.99639527803166, Accuracy:
0.3055848261327713, Hit Rate: 0.4925373134328358, Trades: 938
Running iteration 14/50
30/30             0s 5ms/step
Iteration 14 - Final Portfolio Value: 95.75278970152101, Accuracy:
0.3055848261327713, Hit Rate: 0.487778958554729, Trades: 941
Running iteration 15/50
```

```
30/30             0s 5ms/step
Iteration 15 - Final Portfolio Value: 110.07599748660532, Accuracy:
0.31822971548998946, Hit Rate: 0.5068493150684932, Trades: 949
Running iteration 16/50
30/30             0s 5ms/step
Iteration 16 - Final Portfolio Value: 94.89233192750318, Accuracy:
0.3087460484720759, Hit Rate: 0.4967462039045553, Trades: 922
Running iteration 17/50
30/30             0s 5ms/step
Iteration 17 - Final Portfolio Value: 74.07317988258573, Accuracy:
0.28872497365648053, Hit Rate: 0.4794520547945205, Trades: 949
Running iteration 18/50
30/30             0s 5ms/step
Iteration 18 - Final Portfolio Value: 69.41977170772144, Accuracy:
0.29610115911485774, Hit Rate: 0.462800875273523, Trades: 914
Running iteration 19/50
30/30             0s 5ms/step
Iteration 19 - Final Portfolio Value: 115.39599306269612, Accuracy:
0.32982086406743943, Hit Rate: 0.5164021164021164, Trades: 945
Running iteration 20/50
30/30             0s 5ms/step
Iteration 20 - Final Portfolio Value: 99.0169484989736, Accuracy:
0.3076923076923077, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 21/50
30/30             0s 5ms/step
Iteration 21 - Final Portfolio Value: 89.47703683209613, Accuracy:
0.2982086406743941, Hit Rate: 0.48981779206859594, Trades: 933
Running iteration 22/50
30/30             0s 5ms/step
Iteration 22 - Final Portfolio Value: 115.89544270123115, Accuracy:
0.32771338250790305, Hit Rate: 0.5091891891891892, Trades: 925
Running iteration 23/50
30/30             0s 5ms/step
Iteration 23 - Final Portfolio Value: 106.56911410277418, Accuracy:
0.3150684931506849, Hit Rate: 0.5068493150684932, Trades: 949
Running iteration 24/50
30/30             0s 5ms/step
Iteration 24 - Final Portfolio Value: 107.46998726744, Accuracy:
0.3287671232876712, Hit Rate: 0.5160142348754448, Trades: 843
Running iteration 25/50
30/30             0s 5ms/step
Iteration 25 - Final Portfolio Value: 96.97455178632198, Accuracy:
0.31401475237091675, Hit Rate: 0.49775280898876406, Trades: 890
Running iteration 26/50
30/30             0s 5ms/step
Iteration 26 - Final Portfolio Value: 120.52474215901923, Accuracy:
0.32349841938883034, Hit Rate: 0.5212187159956474, Trades: 919
Running iteration 27/50
```

```
30/30             0s 5ms/step
Iteration 27 - Final Portfolio Value: 81.36459921317608, Accuracy:
0.2929399367755532, Hit Rate: 0.4841628959276018, Trades: 884
Running iteration 28/50
30/30             0s 5ms/step
Iteration 28 - Final Portfolio Value: 122.77553346813586, Accuracy:
0.32982086406743943, Hit Rate: 0.5258166491043204, Trades: 949
Running iteration 29/50
30/30             0s 5ms/step
Iteration 29 - Final Portfolio Value: 109.92246328240817, Accuracy:
0.30979978925184404, Hit Rate: 0.5071193866374589, Trades: 913
Running iteration 30/50
30/30             0s 5ms/step
Iteration 30 - Final Portfolio Value: 93.84626716786511, Accuracy:
0.2950474183350896, Hit Rate: 0.48324324324324325, Trades: 925
Running iteration 31/50
30/30             0s 5ms/step
Iteration 31 - Final Portfolio Value: 100.27510413320316, Accuracy:
0.3076923076923077, Hit Rate: 0.5005268703898841, Trades: 949
Running iteration 32/50
30/30             0s 5ms/step
Iteration 32 - Final Portfolio Value: 107.77919074689298, Accuracy:
0.3245521601685985, Hit Rate: 0.5112059765208111, Trades: 937
Running iteration 33/50
30/30             0s 5ms/step
Iteration 33 - Final Portfolio Value: 87.73639538375237, Accuracy:
0.30453108535300316, Hit Rate: 0.48788198103266595, Trades: 949
Running iteration 34/50
30/30             0s 5ms/step
Iteration 34 - Final Portfolio Value: 93.16718875522675, Accuracy:
0.30242360379346683, Hit Rate: 0.505795574288725, Trades: 949
Running iteration 35/50
30/30             0s 5ms/step
Iteration 35 - Final Portfolio Value: 117.14182845787785, Accuracy:
0.3245521601685985, Hit Rate: 0.5110642781875658, Trades: 949
Running iteration 36/50
30/30             0s 5ms/step
Iteration 36 - Final Portfolio Value: 111.82898703376351, Accuracy:
0.32771338250790305, Hit Rate: 0.5216016859852476, Trades: 949
Running iteration 37/50
30/30             0s 5ms/step
Iteration 37 - Final Portfolio Value: 109.77926031171931, Accuracy:
0.31612223393045313, Hit Rate: 0.5107296137339056, Trades: 932
Running iteration 38/50
30/30             0s 5ms/step
Iteration 38 - Final Portfolio Value: 102.538991128418, Accuracy:
0.3108535300316122, Hit Rate: 0.5064794816414687, Trades: 926
Running iteration 39/50
```

```
30/30            0s 5ms/step
Iteration 39 - Final Portfolio Value: 96.05452129906274, Accuracy:
0.3192834562697576, Hit Rate: 0.49712313003452246, Trades: 869
Running iteration 40/50
30/30            0s 5ms/step
Iteration 40 - Final Portfolio Value: 96.80945893466891, Accuracy:
0.3066385669125395, Hit Rate: 0.4952581664910432, Trades: 949
Running iteration 41/50
30/30            0s 5ms/step
Iteration 41 - Final Portfolio Value: 90.66632988956874, Accuracy:
0.30979978925184404, Hit Rate: 0.48292682926829267, Trades: 820
Running iteration 42/50
30/30            0s 5ms/step
Iteration 42 - Final Portfolio Value: 104.55756842524744, Accuracy:
0.3192834562697576, Hit Rate: 0.5011792452830188, Trades: 848
Running iteration 43/50
30/30            0s 5ms/step
Iteration 43 - Final Portfolio Value: 99.0169484989736, Accuracy:
0.3076923076923077, Hit Rate: 0.5015806111696522, Trades: 949
Running iteration 44/50
30/30            0s 5ms/step
Iteration 44 - Final Portfolio Value: 108.11888550178291, Accuracy:
0.31822971548998946, Hit Rate: 0.5148842337375965, Trades: 907
Running iteration 45/50
30/30            0s 5ms/step
Iteration 45 - Final Portfolio Value: 104.34531959658183, Accuracy:
0.3087460484720759, Hit Rate: 0.4931506849315068, Trades: 949
Running iteration 46/50
30/30            0s 5ms/step
Iteration 46 - Final Portfolio Value: 97.01283407628812, Accuracy:
0.3087460484720759, Hit Rate: 0.5005268703898841, Trades: 949
Running iteration 47/50
30/30            0s 5ms/step
Iteration 47 - Final Portfolio Value: 89.10775032203104, Accuracy:
0.3329820864067439, Hit Rate: 0.48027210884353744, Trades: 735
Running iteration 48/50
30/30            0s 5ms/step
Iteration 48 - Final Portfolio Value: 99.49810467896414, Accuracy:
0.3150684931506849, Hit Rate: 0.4994731296101159, Trades: 949
Running iteration 49/50
30/30            0s 5ms/step
Iteration 49 - Final Portfolio Value: 110.99513651394774, Accuracy:
0.321390937829294, Hit Rate: 0.5131717597471022, Trades: 949
Running iteration 50/50
30/30            0s 5ms/step
Iteration 50 - Final Portfolio Value: 99.81854620729685, Accuracy:
0.30453108535300316, Hit Rate: 0.4952581664910432, Trades: 949
Average Final Portfolio Value:
```

```
100.5447499871735
Standard Deviation of Final Values:
10.643099451474878
Average Accuracy:
0.31251844046364596
Average Hit Rate:
0.5004410216934921
Average No. of Trades:
923.14
```

8 5th Iteration

[ ]:
```
time_steps = 15

dataX = create_dataset(dataset, time_steps)

dataX = np.reshape(dataX, (dataX.shape[0], time_steps, dataset.shape[1]))

X = dataX
y = y_categories[time_steps:]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,␣
↪shuffle=False)
```

[ ]:
```
def create_model_5(units1 = 128, dropout_rate1 = 0.3, batch_size = 32, l2_value␣
↪= 0.01):
    model = Sequential([
        Input(shape = (X_train.shape[1], X_train.shape[2])),
        LSTM(units1, return_sequences = False),
        Dropout(dropout_rate1),
        Dense(3, activation = 'softmax', kernel_regularizer = l2(l2_value))
    ])
    model.compile(optimizer = 'adam', loss = 'categorical_crossentropy',␣
↪metrics = ['accuracy'])
    return model
```

[ ]:
```
model_5 = KerasClassifier(model = create_model_5, epochs = 75, verbose = 0,␣
↪shuffle = False, random_state = 42)
```

[ ]:
```
param_grid_model5 = {
    'model__units1': [32, 64, 128],
    'model__dropout_rate1': [0.4, 0.3, 0.2],
    'batch_size': [32, 64, 128],
    'model__l2_value': [0.1, 0.05, 0.02]
}
```

[ ]:
```
grid_model_5 = GridSearchCV(estimator = model_5, param_grid =␣
↪param_grid_model5, cv = 5, n_jobs = -1)
```

[ ]:
```
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
↪start_from_epoch = 10, restore_best_weights = True)

grid_result_model_5 = grid_model_5.fit(X_train, y_train, validation_split = 0.
↪2, callbacks = [early_stopping])
```

[ ]:
```
best_params_model_5 = grid_result_model_5.best_params_

print(best_params_model_5)
```

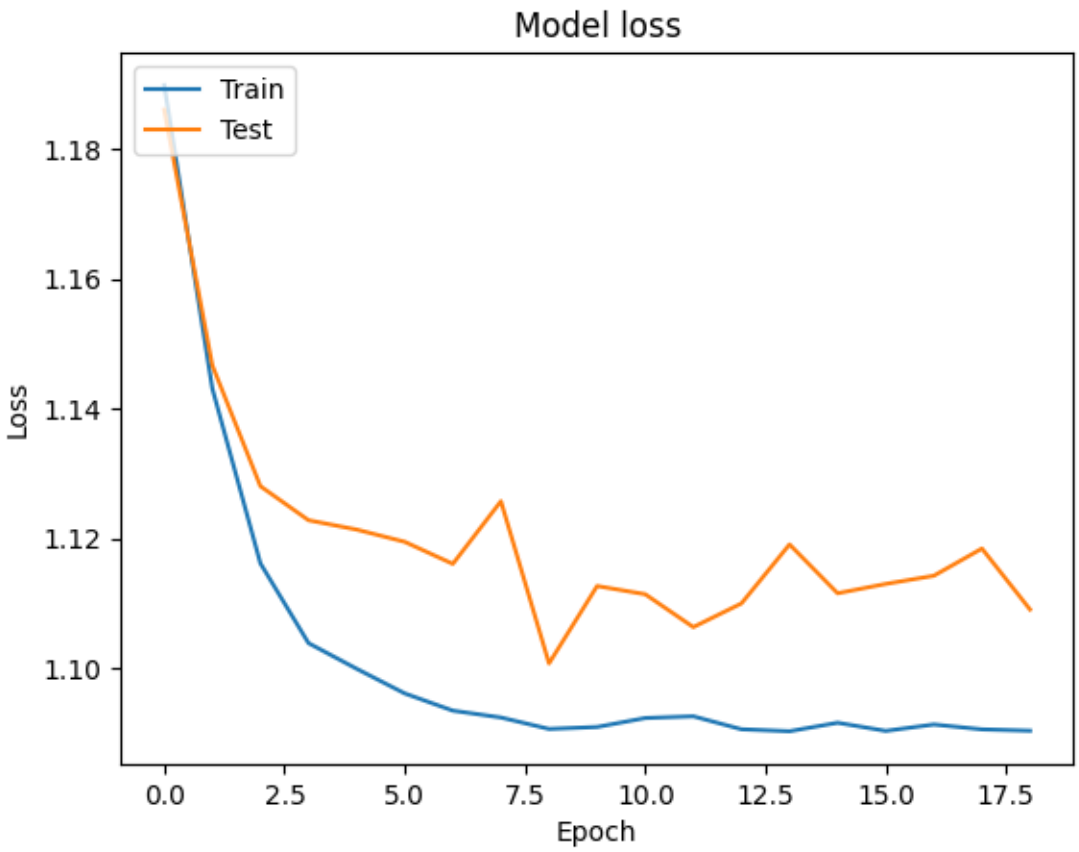
```
{'batch_size': 64, 'model__dropout_rate1': 0.3, 'model__l2_value': 0.02,
'model__units1': 128}
```

[ ]:
```
best_model_5 = create_model_5(units1 = best_params_model_5['model__units1'],
                              dropout_rate1 =␣
↪best_params_model_5['model__dropout_rate1'],
                              batch_size = best_params_model_5['batch_size'],
                              l2_value = best_params_model_5['model__l2_value'],
                              )
```

[ ]:
```
early_stopping_manual = EarlyStopping(monitor = 'val_loss', patience = 10,␣
↪restore_best_weights = True)

history_model_5 = best_model_5.fit(X_train, y_train,
                           epochs = 75,
                           validation_data=(X_test, y_test),
                                     batch_size = 64, # remember to change if␣
↪needed (default = 32)
                          callbacks = [early_stopping_manual],
                           verbose = 0)
```

[ ]:
```
plt.plot(history_model_5.history['loss'])
plt.plot(history_model_5.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```



[ ]:
```
y_pred = best_model_5.predict(X_test)

actual_categories = np.argmax(y_test, axis=1)

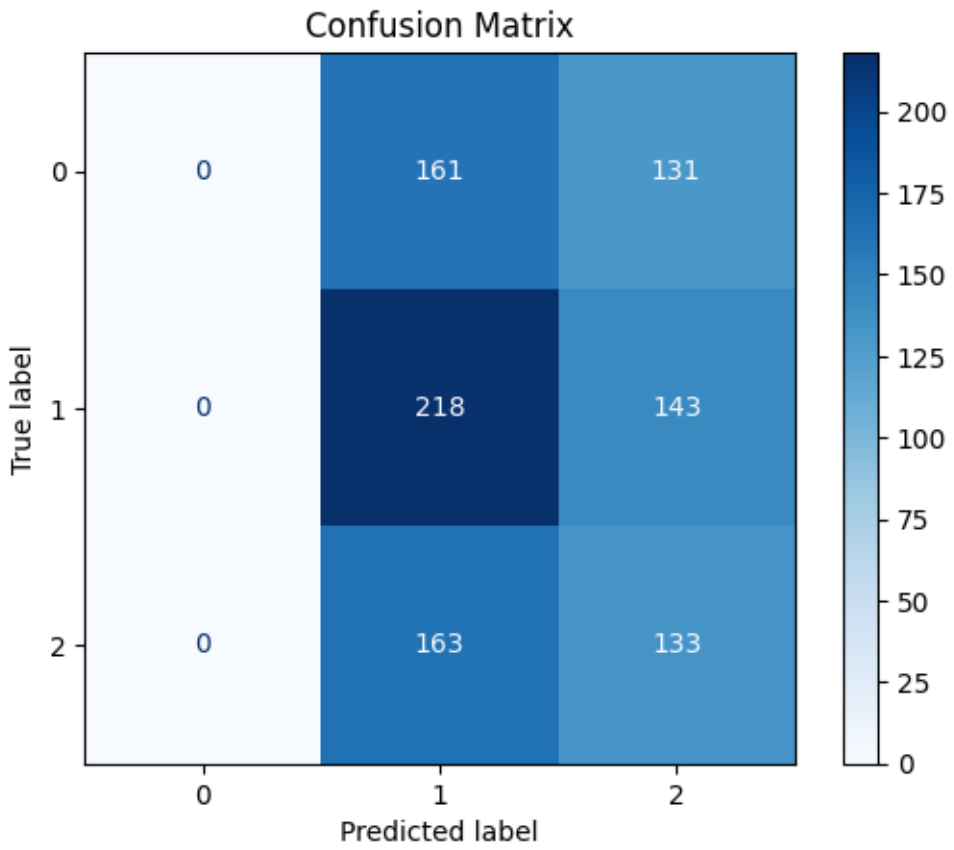
predicted_categories = np.argmax(y_pred, axis=1)

cm = confusion_matrix(actual_categories, predicted_categories)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1, 2])

plt.figure(figsize=(10, 7))
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()
```

```
30/30              0s 5ms/step
```

```
<Figure size 1000x700 with 0 Axes>
```



[ ]:
```
def compute_hit_rate(signals, percent_changes):
    correct_signals = 0
    total_signals = len(signals)

    for signal, percent_change in zip(signals, percent_changes):
        if (signal == 0 and percent_change < 0) or (signal == 2 and␣
 ↪percent_change > 0):
            correct_signals += 1
        elif signal == 1:
            total_signals -= 1

    return correct_signals / total_signals if total_signals > 0 else 0

def backtest(actions, percent_changes):
    cash = 100
    position = 0
    portfolio_value = []

    for action, percent_change in zip(actions, percent_changes):
```

```
        if action == 0:  # Sell
            position = -100  # Set position to short
            cash += position * percent_change  # Sell shares
        elif action == 1:  # Flat
            position = 0  # Set position to flat
            cash += 0  # No action
        elif action == 2:  # Buy
            position = 100  # Set position to long
            cash += position * percent_change  # Buy shares

        portfolio_value.append(cash)  # Calculate portfolio value

    return portfolio_value

def run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_5):
    best_model_5 = create_model_5(units1 = best_params_model_5['model__units1'],
                           dropout_rate1 =␣
 ↪best_params_model_5['model__dropout_rate1'],
                           batch_size = best_params_model_5['batch_size'],
                           l2_value = best_params_model_5['model__l2_value'],
                           )

    early_stopping_manual = EarlyStopping(monitor = 'val_loss', patience = 10,␣
 ↪restore_best_weights = True)

    history_model_5 = best_model_5.fit(X_train, y_train,
                          epochs = 75,
                          validation_data=(X_test, y_test),
                                    batch_size = 128, # remember to change if␣
 ↪needed (default = 32)
                         callbacks = [early_stopping_manual],
                          verbose = 0)

    predictions = best_model_5.predict(X_test)
    predicted_categories = np.argmax(predictions, axis=1)

    y_test_labels = np.argmax(y_test, axis=1)

    accuracy = accuracy_score(y_test_labels, predicted_categories)

    signals = predicted_categories
    percent_changes = np.array(df_raw_exchange.iloc[-len(y_test):])

    portfolio_value = backtest(signals, percent_changes)
    hit_rate = compute_hit_rate(signals, percent_changes)
    num_trades = np.sum((signals == 0) | (signals == 2))
```

```
    return portfolio_value, accuracy, hit_rate, num_trades

iterations = 50

final_portfolio_values = []
accuracies = []
hit_rates = []
trade_counts = []

for i in range(iterations):
    print(f"Running iteration {i+1}/{iterations}")
    portfolio_value, accuracy, hit_rate, num_trades =␣
 ↪run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_5)
    final_portfolio_values.append(portfolio_value[-1])
    accuracies.append(accuracy)
    hit_rates.append(hit_rate)
    trade_counts.append(num_trades)
    print(f"Iteration {i+1} - Final Portfolio Value: {portfolio_value[-1]},␣
 ↪Accuracy: {accuracy}, Hit Rate: {hit_rate}, Trades: {num_trades}")

average_final_value = np.mean(final_portfolio_values)
std_final_value = np.std(final_portfolio_values)

average_accuracy = np.mean(accuracies)
average_hit_rate = np.mean(hit_rates)
average_num_trades = np.mean(trade_counts)

print("Average Final Portfolio Value:")
print(average_final_value)
print('Standard Deviation of Final Values:')
print(std_final_value)
print('Average Accuracy:')
print(average_accuracy)
print('Average Hit Rate:')
print(average_hit_rate)
print('Average No. of Trades:')
print(average_num_trades)
```

```
Running iteration 1/50
30/30             0s 5ms/step
Iteration 1 - Final Portfolio Value: 94.13046969356863, Accuracy:
0.36459430979978924, Hit Rate: 0.49184149184149184, Trades: 429
Running iteration 2/50
30/30             0s 5ms/step
Iteration 2 - Final Portfolio Value: 100.69232340578806, Accuracy:
0.37513171759747105, Hit Rate: 0.5212765957446809, Trades: 376
```

```
Running iteration 3/50
30/30             0s 5ms/step
Iteration 3 - Final Portfolio Value: 96.50114863431183, Accuracy:
0.3656480505795574, Hit Rate: 0.5, Trades: 430
Running iteration 4/50
30/30             0s 5ms/step
Iteration 4 - Final Portfolio Value: 106.04233815660174, Accuracy:
0.35932560590094836, Hit Rate: 0.5024630541871922, Trades: 609
Running iteration 5/50
30/30             0s 5ms/step
Iteration 5 - Final Portfolio Value: 98.67808816285509, Accuracy:
0.36459430979978924, Hit Rate: 0.5155555555555555, Trades: 450
Running iteration 6/50
30/30             0s 5ms/step
Iteration 6 - Final Portfolio Value: 102.66773848615868, Accuracy:
0.3624868282402529, Hit Rate: 0.500763358778626, Trades: 655
Running iteration 7/50
30/30             0s 5ms/step
Iteration 7 - Final Portfolio Value: 98.55969371445802, Accuracy:
0.3677555321390938, Hit Rate: 0.5098039215686274, Trades: 459
Running iteration 8/50
30/30             0s 5ms/step
Iteration 8 - Final Portfolio Value: 89.00535917268758, Accuracy:
0.3719704952581665, Hit Rate: 0.4644808743169399, Trades: 366
Running iteration 9/50
30/30             0s 4ms/step
Iteration 9 - Final Portfolio Value: 104.14130723750851, Accuracy:
0.3582718651211802, Hit Rate: 0.5015974440894568, Trades: 626
Running iteration 10/50
30/30             0s 5ms/step
Iteration 10 - Final Portfolio Value: 107.63490867427532, Accuracy:
0.3667017913593256, Hit Rate: 0.5104761904761905, Trades: 525
Running iteration 11/50
30/30             0s 5ms/step
Iteration 11 - Final Portfolio Value: 109.01479036379922, Accuracy:
0.36880927291886195, Hit Rate: 0.5194805194805194, Trades: 616
Running iteration 12/50
30/30             0s 5ms/step
Iteration 12 - Final Portfolio Value: 100.15172796070615, Accuracy:
0.37407797681770283, Hit Rate: 0.5223880597014925, Trades: 402
Running iteration 13/50
30/30             0s 5ms/step
Iteration 13 - Final Portfolio Value: 105.9767716493679, Accuracy:
0.3698630136986301, Hit Rate: 0.5033670033670034, Trades: 594
Running iteration 14/50
30/30             0s 5ms/step
Iteration 14 - Final Portfolio Value: 104.9038311701035, Accuracy:
0.3804004214963119, Hit Rate: 0.4930747922437673, Trades: 361
```

```
Running iteration 15/50
30/30             0s 5ms/step
Iteration 15 - Final Portfolio Value: 93.05528795849634, Accuracy:
0.3656480505795574, Hit Rate: 0.4934782608695652, Trades: 460
Running iteration 16/50
30/30             0s 5ms/step
Iteration 16 - Final Portfolio Value: 98.95024596786416, Accuracy:
0.3656480505795574, Hit Rate: 0.5128205128205128, Trades: 429
Running iteration 17/50
30/30             0s 5ms/step
Iteration 17 - Final Portfolio Value: 105.47283682437114, Accuracy:
0.37091675447839834, Hit Rate: 0.5025125628140703, Trades: 597
Running iteration 18/50
30/30             0s 5ms/step
Iteration 18 - Final Portfolio Value: 99.20919137261156, Accuracy:
0.3635405690200211, Hit Rate: 0.5133689839572193, Trades: 561
Running iteration 19/50
30/30             0s 5ms/step
Iteration 19 - Final Portfolio Value: 105.75240854056246, Accuracy:
0.37091675447839834, Hit Rate: 0.5033670033670034, Trades: 594
Running iteration 20/50
30/30             0s 5ms/step
Iteration 20 - Final Portfolio Value: 93.4439101771945, Accuracy:
0.36459430979978924, Hit Rate: 0.4869109947643979, Trades: 573
Running iteration 21/50
30/30             0s 5ms/step
Iteration 21 - Final Portfolio Value: 108.1003111794076, Accuracy:
0.3635405690200211, Hit Rate: 0.5094664371772806, Trades: 581
Running iteration 22/50
30/30             0s 5ms/step
Iteration 22 - Final Portfolio Value: 110.56754336056228, Accuracy:
0.3677555321390938, Hit Rate: 0.5080906148867314, Trades: 618
Running iteration 23/50
30/30             0s 5ms/step
Iteration 23 - Final Portfolio Value: 111.18816731969234, Accuracy:
0.37302423603793466, Hit Rate: 0.5094043887147336, Trades: 638
Running iteration 24/50
30/30             0s 5ms/step
Iteration 24 - Final Portfolio Value: 105.84809257660437, Accuracy:
0.3677555321390938, Hit Rate: 0.5022421524663677, Trades: 446
Running iteration 25/50
30/30             0s 5ms/step
Iteration 25 - Final Portfolio Value: 95.7283816476421, Accuracy:
0.3582718651211802, Hit Rate: 0.4899598393574297, Trades: 498
Running iteration 26/50
30/30             0s 5ms/step
Iteration 26 - Final Portfolio Value: 102.15518221506282, Accuracy:
0.3793466807165437, Hit Rate: 0.48717948717948717, Trades: 351
```

```
Running iteration 27/50
30/30             0s 5ms/step
Iteration 27 - Final Portfolio Value: 106.98235173379945, Accuracy:
0.3677555321390938, Hit Rate: 0.5105973025048169, Trades: 519
Running iteration 28/50
30/30             0s 4ms/step
Iteration 28 - Final Portfolio Value: 101.74394789263584, Accuracy:
0.3624868282402529, Hit Rate: 0.502835538752363, Trades: 529
Running iteration 29/50
30/30             0s 5ms/step
Iteration 29 - Final Portfolio Value: 90.23908432438192, Accuracy:
0.3403582718651212, Hit Rate: 0.48484848484848486, Trades: 660
Running iteration 30/50
30/30             0s 5ms/step
Iteration 30 - Final Portfolio Value: 83.69798330480765, Accuracy:
0.3719704952581665, Hit Rate: 0.4619718309859155, Trades: 355
Running iteration 31/50
30/30             0s 5ms/step
Iteration 31 - Final Portfolio Value: 94.77721663058988, Accuracy:
0.3667017913593256, Hit Rate: 0.4982638888888889, Trades: 576
Running iteration 32/50
30/30             0s 5ms/step
Iteration 32 - Final Portfolio Value: 97.62978775670952, Accuracy:
0.3656480505795574, Hit Rate: 0.5012165450121655, Trades: 411
Running iteration 33/50
30/30             0s 4ms/step
Iteration 33 - Final Portfolio Value: 103.08974086851352, Accuracy:
0.3656480505795574, Hit Rate: 0.5176470588235295, Trades: 595
Running iteration 34/50
30/30             0s 5ms/step
Iteration 34 - Final Portfolio Value: 98.43742585051467, Accuracy:
0.3487881981032666, Hit Rate: 0.49333333333333335, Trades: 675
Running iteration 35/50
30/30             0s 5ms/step
Iteration 35 - Final Portfolio Value: 102.0291468765601, Accuracy:
0.3656480505795574, Hit Rate: 0.5259593679458239, Trades: 443
Running iteration 36/50
30/30             0s 5ms/step
Iteration 36 - Final Portfolio Value: 99.26763905237128, Accuracy:
0.35932560590094836, Hit Rate: 0.5092748735244519, Trades: 593
Running iteration 37/50
30/30             0s 5ms/step
Iteration 37 - Final Portfolio Value: 104.75311697807646, Accuracy:
0.3656480505795574, Hit Rate: 0.4966139954853273, Trades: 443
Running iteration 38/50
30/30             0s 4ms/step
Iteration 38 - Final Portfolio Value: 92.20792061068913, Accuracy:
0.3308746048472076, Hit Rate: 0.48725212464589235, Trades: 706
```

```
Running iteration 39/50
30/30             0s 5ms/step
Iteration 39 - Final Portfolio Value: 97.25428153648149, Accuracy:
0.37513171759747105, Hit Rate: 0.5012787723785166, Trades: 391
Running iteration 40/50
30/30             0s 5ms/step
Iteration 40 - Final Portfolio Value: 105.04621945556367, Accuracy:
0.34351949420442573, Hit Rate: 0.496551724137931, Trades: 725
Running iteration 41/50
30/30             0s 5ms/step
Iteration 41 - Final Portfolio Value: 101.46842045826634, Accuracy:
0.3761854583772392, Hit Rate: 0.5239234449760766, Trades: 418
Running iteration 42/50
30/30             0s 5ms/step
Iteration 42 - Final Portfolio Value: 103.92546245240149, Accuracy:
0.35721812434141204, Hit Rate: 0.4975767366720517, Trades: 619
Running iteration 43/50
30/30             0s 5ms/step
Iteration 43 - Final Portfolio Value: 105.37526740466335, Accuracy:
0.37513171759747105, Hit Rate: 0.5, Trades: 410
Running iteration 44/50
30/30             0s 5ms/step
Iteration 44 - Final Portfolio Value: 105.79365334276243, Accuracy:
0.36880927291886195, Hit Rate: 0.5034843205574913, Trades: 574
Running iteration 45/50
30/30             0s 5ms/step
Iteration 45 - Final Portfolio Value: 86.97200819454902, Accuracy:
0.3635405690200211, Hit Rate: 0.4530612244897959, Trades: 245
Running iteration 46/50
30/30             0s 5ms/step
Iteration 46 - Final Portfolio Value: 92.15834018186172, Accuracy:
0.35721812434141204, Hit Rate: 0.48333333333333334, Trades: 480
Running iteration 47/50
30/30             0s 5ms/step
Iteration 47 - Final Portfolio Value: 104.58267888709221, Accuracy:
0.36880927291886195, Hit Rate: 0.5098425196850394, Trades: 508
Running iteration 48/50
30/30             0s 5ms/step
Iteration 48 - Final Portfolio Value: 104.54110268242476, Accuracy:
0.35932560590094836, Hit Rate: 0.5031578947368421, Trades: 475
Running iteration 49/50
30/30             0s 5ms/step
Iteration 49 - Final Portfolio Value: 103.98059063323939, Accuracy:
0.37302423603793466, Hit Rate: 0.5, Trades: 490
Running iteration 50/50
30/30             0s 5ms/step
Iteration 50 - Final Portfolio Value: 94.76367123943398, Accuracy:
0.3119072708113804, Hit Rate: 0.4828850855745721, Trades: 818
```

```
Average Final Portfolio Value:
100.56578227941301
Standard Deviation of Final Values:
6.174693736929815
Average Accuracy:
0.36402528977871446
Average Hit Rate:
0.5004055900203797
Average No. of Trades:
518.04
```

9 6th Iteration

[ ]:
```
time_steps = 15

dataX = create_dataset(dataset, time_steps)

dataX = np.reshape(dataX, (dataX.shape[0], time_steps, dataset.shape[1]))

X = dataX
y = y_categories[time_steps:]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size = 0.2,␣
 ↪shuffle = False, random_state = 42)
```

[ ]:
```
def create_model_6(units1 = 128, units2 = 64,  dropout_rate1 = 0.2,␣
 ↪dropout_rate2 = 0.1, batch_size = 32, l2_value = 0.01):
    model = Sequential([
        Input(shape = (X_train.shape[1], X_train.shape[2])),
        LSTM(units1, return_sequences = True),
        Dropout(dropout_rate1),
        LSTM(units2, return_sequences = False),
        Dropout(dropout_rate2),
        Dense(3, activation = 'softmax', kernel_regularizer = l2(l2_value))
    ])
    model.compile(optimizer = 'adam', loss = 'categorical_crossentropy',␣
 ↪metrics = ['accuracy'])
    return model
```

[ ]:
```
param_grid_model_6 = {
    'model__units1': [64, 128],
    'model__units2': [64, 128],
    'model__dropout_rate1': [0.2, 0.3, 0.4],
    'model__dropout_rate2': [0.2, 0.3, 0.4],
    'batch_size': [64, 128],
    'model__l2_value': [0.1, 0.01]
}
```

```
[ ]: model_6 = KerasClassifier(model = create_model_6, epochs = 75, verbose = 0,␣
      ↪shuffle = False, random_state = 42)
```

```
[ ]: grid_model_6 = GridSearchCV(estimator = model_6, param_grid =␣
      ↪param_grid_model_6, cv=5, scoring = 'accuracy', n_jobs = -1)
```

```
[ ]: early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
      ↪start_from_epoch = 10, restore_best_weights = True)

     grid_result_model_6 = grid_model_6.fit(X_train, y_train, validation_split = 0.
      ↪2, callbacks = [early_stopping])
```

```
[ ]: best_params_model_6 = grid_result_model_6.best_params_

     print(best_params_model_6)
```

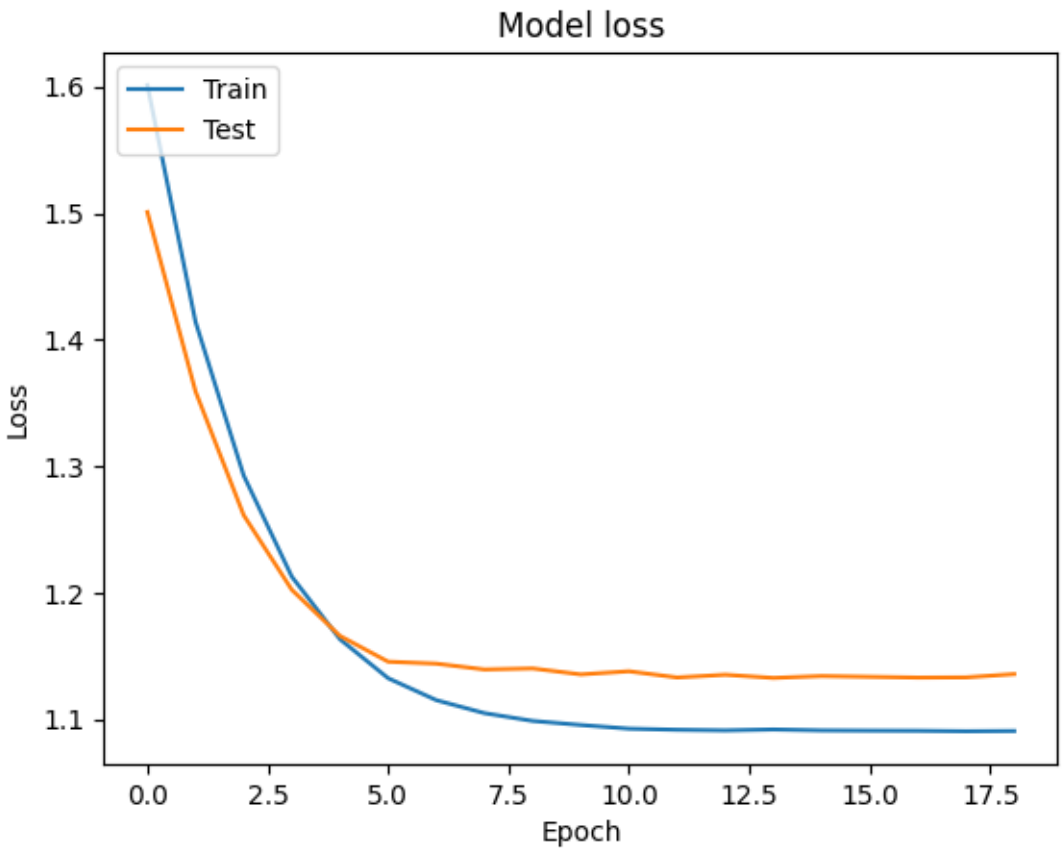
```
{'batch_size': 128, 'model__dropout_rate1': 0.4, 'model__dropout_rate2': 0.4,
'model__l2_value': 0.1, 'model__units1': 128, 'model__units2': 128}
```

```
[ ]: best_model_6 = create_model_6(units1 = best_params_model_6['model__units1'],
                                  units2 = best_params_model_6['model__units2'],
                               dropout_rate1 =␣
      ↪best_params_model_6['model__dropout_rate1'],
                                  dropout_rate2 =␣
      ↪best_params_model_6['model__dropout_rate2'],
                               batch_size = best_params_model_6['batch_size'],
                                  l2_value = best_params_model_6['model__l2_value']
                               )
```

```
[ ]: early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
      ↪start_from_epoch = 10, restore_best_weights = True)

     history_model_6 = best_model_6.fit(X_train, y_train,
                              epochs=75,
                                        batch_size = 128, # remember to change␣
      ↪(default = 32)
                              validation_data = (X_test, y_test),
                                        callbacks = [early_stopping],
                              verbose = 0)
```

```
[ ]: plt.plot(history_model_6.history['loss'])
     plt.plot(history_model_6.history['val_loss'])
     plt.title('Model loss')
     plt.ylabel('Loss')
     plt.xlabel('Epoch')
     plt.legend(['Train', 'Test'], loc='upper left')
     plt.show()
```



[ ]:
```
y_pred = best_model_6.predict(X_test)

actual_categories = np.argmax(y_test, axis=1)

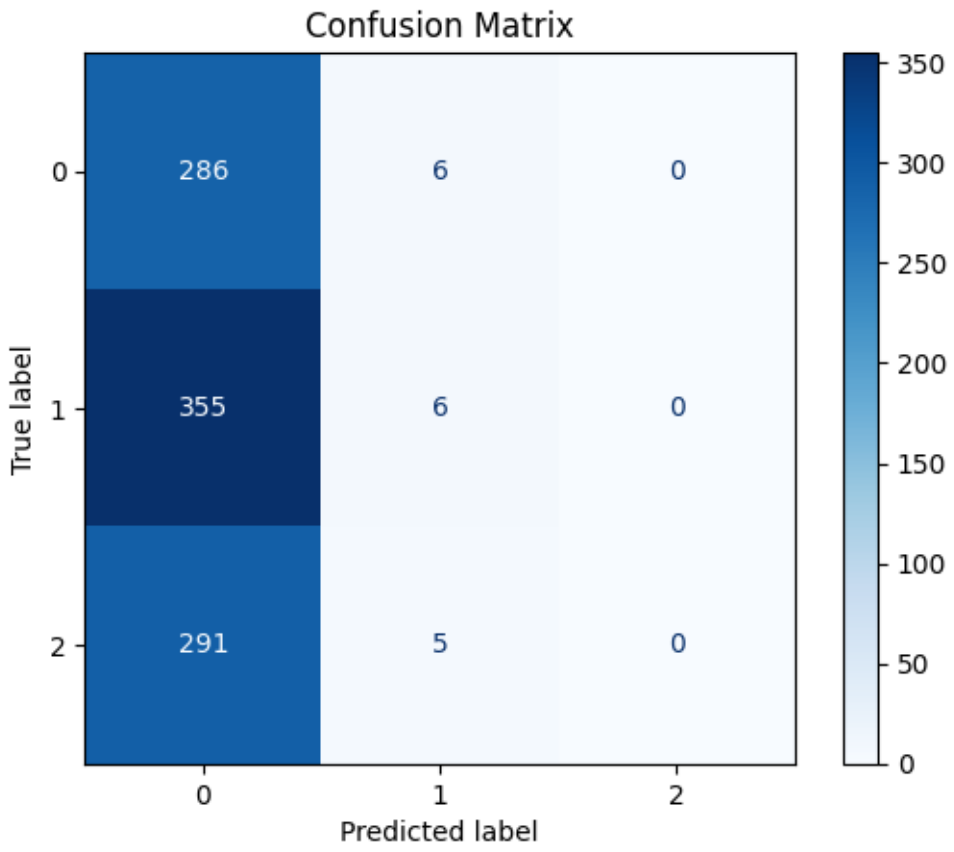
predicted_categories = np.argmax(y_pred, axis=1)

cm = confusion_matrix(actual_categories, predicted_categories)
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=[0, 1, 2])

plt.figure(figsize=(10, 7))
disp.plot(cmap=plt.cm.Blues)
plt.title('Confusion Matrix')
plt.show()
```

```
30/30              0s 3ms/step
```

```
<Figure size 1000x700 with 0 Axes>
```



[ ]:
```
def compute_hit_rate(signals, percent_changes):
    correct_signals = 0
    total_signals = len(signals)

    for signal, percent_change in zip(signals, percent_changes):
        if (signal == 0 and percent_change < 0) or (signal == 2 and␣
 ↪percent_change > 0):
            correct_signals += 1
        elif signal == 1:
            total_signals -= 1

    return correct_signals / total_signals if total_signals > 0 else 0

def backtest(actions, percent_changes):
    cash = 100
    position = 0
    portfolio_value = []

    for action, percent_change in zip(actions, percent_changes):
```

```
        if action == 0:  # Sell
            position = -100  # Set position to short
            cash += position * percent_change  # Sell shares
        elif action == 1:  # Flat
            position = 0  # Set position to flat
            cash += 0  # No action
        elif action == 2:  # Buy
            position = 100  # Set position to long
            cash += position * percent_change  # Buy shares

        portfolio_value.append(cash)

    return portfolio_value

def run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_6):
    best_model_6 = create_model_6(units1 = best_params_model_6['model__units1'],
                                  units2 = best_params_model_6['model__units2'],
                              dropout_rate1 =␣
 ↪best_params_model_6['model__dropout_rate1'],
                                  dropout_rate2 =␣
 ↪best_params_model_6['model__dropout_rate2'],
                              batch_size = best_params_model_6['batch_size'],
                                  l2_value = best_params_model_6['model__l2_value']
                              )

    early_stopping = EarlyStopping(monitor = 'val_loss', patience = 5,␣
 ↪start_from_epoch = 10, restore_best_weights = True)

    history_model_6 = best_model_6.fit(X_train, y_train,
                          epochs = 75,
                                    batch_size = 128,
                          validation_data = (X_test, y_test),
                                    callbacks = [early_stopping],
                          verbose = 0)

    predictions = best_model_6.predict(X_test)
    predicted_categories = np.argmax(predictions, axis=1)

    y_test_labels = np.argmax(y_test, axis=1)

    accuracy = accuracy_score(y_test_labels, predicted_categories)

    signals = predicted_categories
    percent_changes = np.array(df_raw_exchange.iloc[-len(y_test):])

    portfolio_value = backtest(signals, percent_changes)
    hit_rate = compute_hit_rate(signals, percent_changes)
```

```
    num_trades = np.sum((signals == 0) | (signals == 2))


    return portfolio_value, accuracy, hit_rate, num_trades

iterations = 50

final_portfolio_values = []
accuracies = []
hit_rates = []
trade_counts = []

for i in range(iterations):
    print(f"Running iteration {i+1}/{iterations}")
    portfolio_value, accuracy, hit_rate, num_trades =␣
 ↪run_single_iteration(X_train, y_train, X_test, y_test, best_params_model_6)
    final_portfolio_values.append(portfolio_value[-1])
    accuracies.append(accuracy)
    hit_rates.append(hit_rate)
    trade_counts.append(num_trades)
    print(f"Iteration {i+1} - Final Portfolio Value: {portfolio_value[-1]},␣
 ↪Accuracy: {accuracy}, Hit Rate: {hit_rate}, Trades: {num_trades}")

average_final_value = np.mean(final_portfolio_values)
std_final_value = np.std(final_portfolio_values)

average_accuracy = np.mean(accuracies)
average_hit_rate = np.mean(hit_rates)
average_num_trades = np.mean(trade_counts)

print("Average Final Portfolio Value:")
print(average_final_value)
print('Standard Deviation of Final Values:')
print(std_final_value)
print('Average Accuracy:')
print(average_accuracy)
print('Average Hit Rate:')
print(average_hit_rate)
print('Average No. of Trades:')
print(average_num_trades)
```

```
Running iteration 1/100
30/30             0s 8ms/step
Iteration 1 - Final Portfolio Value: 96.55242852422245, Accuracy:
0.2971548998946259, Hit Rate: 0.5005820721769499, Trades: 859
Running iteration 2/100
30/30             0s 9ms/step
```

```
Iteration 2 - Final Portfolio Value: 88.65577949152967, Accuracy:
0.303477344573235, Hit Rate: 0.4944920440636475, Trades: 817
Running iteration 3/100
30/30             0s 8ms/step
Iteration 3 - Final Portfolio Value: 85.71726513449345, Accuracy:
0.3129610115911486, Hit Rate: 0.48673740053050396, Trades: 754
Running iteration 4/100
30/30             0s 8ms/step
Iteration 4 - Final Portfolio Value: 86.81982416582764, Accuracy:
0.2992623814541623, Hit Rate: 0.4841075794621027, Trades: 818
Running iteration 5/100
30/30             0s 8ms/step
Iteration 5 - Final Portfolio Value: 97.49341471902477, Accuracy:
0.303477344573235, Hit Rate: 0.5011764705882353, Trades: 850
Running iteration 6/100
30/30             0s 8ms/step
Iteration 6 - Final Portfolio Value: 89.05121708502034, Accuracy:
0.3066385669125395, Hit Rate: 0.49622166246851385, Trades: 794
Running iteration 7/100
30/30             0s 8ms/step
Iteration 7 - Final Portfolio Value: 88.05377843736355, Accuracy:
0.30242360379346683, Hit Rate: 0.4981640146878825, Trades: 817
Running iteration 8/100
30/30             0s 8ms/step
Iteration 8 - Final Portfolio Value: 96.21417981798945, Accuracy:
0.30242360379346683, Hit Rate: 0.505338078291815, Trades: 843
Running iteration 9/100
30/30             0s 8ms/step
Iteration 9 - Final Portfolio Value: 97.09337229078186, Accuracy:
0.3287671232876712, Hit Rate: 0.5006915629322268, Trades: 723
Running iteration 10/100
30/30             0s 8ms/step
Iteration 10 - Final Portfolio Value: 92.06531236961206, Accuracy:
0.3192834562697576, Hit Rate: 0.502724795640327, Trades: 734
Running iteration 11/100
30/30             0s 8ms/step
Iteration 11 - Final Portfolio Value: 85.34426682957171, Accuracy:
0.31401475237091675, Hit Rate: 0.4808743169398907, Trades: 732
Running iteration 12/100
30/30             0s 8ms/step
Iteration 12 - Final Portfolio Value: 91.02584055634307, Accuracy:
0.3076923076923077, Hit Rate: 0.4944237918215613, Trades: 807
Running iteration 13/100
30/30             0s 8ms/step
Iteration 13 - Final Portfolio Value: 83.27268302010543, Accuracy:
0.29610115911485774, Hit Rate: 0.486810551558753, Trades: 834
Running iteration 14/100
30/30             0s 8ms/step
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Iteration 14 - Final Portfolio Value: 92.34673546378897, Accuracy:
0.2950474183350896, Hit Rate: 0.49824150058616645, Trades: 853
Running iteration 15/100
30/30             0s 8ms/step
Iteration 15 - Final Portfolio Value: 90.50210322968485, Accuracy:
0.3119072708113804, Hit Rate: 0.49546044098573283, Trades: 771
Running iteration 16/100
30/30             0s 8ms/step
Iteration 16 - Final Portfolio Value: 90.68482910623345, Accuracy:
0.3150684931506849, Hit Rate: 0.4961340206185567, Trades: 776
Running iteration 17/100
30/30             0s 8ms/step
Iteration 17 - Final Portfolio Value: 81.71136239667632, Accuracy:
0.29083245521601686, Hit Rate: 0.4773561811505508, Trades: 817
Running iteration 18/100
30/30             0s 8ms/step
Iteration 18 - Final Portfolio Value: 86.70130347769086, Accuracy:
0.3055848261327713, Hit Rate: 0.49815043156596794, Trades: 811
Running iteration 19/100
30/30             0s 8ms/step
Iteration 19 - Final Portfolio Value: 102.1668412756319, Accuracy:
0.3624868282402529, Hit Rate: 0.4975124378109453, Trades: 603
Running iteration 20/100
30/30             0s 8ms/step
Iteration 20 - Final Portfolio Value: 85.98576294513194, Accuracy:
0.29610115911485774, Hit Rate: 0.4897466827503016, Trades: 829
Running iteration 21/100
30/30             0s 8ms/step
Iteration 21 - Final Portfolio Value: 85.7124439519323, Accuracy:
0.30242360379346683, Hit Rate: 0.4927710843373494, Trades: 830
Running iteration 22/100
30/30             0s 8ms/step
Iteration 22 - Final Portfolio Value: 90.02341105267979, Accuracy:
0.30453108535300316, Hit Rate: 0.49255583126550867, Trades: 806
Running iteration 23/100
30/30             0s 8ms/step
Iteration 23 - Final Portfolio Value: 89.62477575320878, Accuracy:
0.3087460484720759, Hit Rate: 0.49370277078085645, Trades: 794
Running iteration 24/100
30/30             0s 8ms/step
Iteration 24 - Final Portfolio Value: 84.82767260462924, Accuracy:
0.2992623814541623, Hit Rate: 0.4963942307692308, Trades: 832
Running iteration 25/100
30/30             0s 8ms/step
Iteration 25 - Final Portfolio Value: 89.08683112821805, Accuracy:
0.3066385669125395, Hit Rate: 0.4920828258221681, Trades: 821
Running iteration 26/100
30/30             0s 8ms/step
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Iteration 26 - Final Portfolio Value: 94.63546311592944, Accuracy:
0.3119072708113804, Hit Rate: 0.5006090133982948, Trades: 821
Running iteration 27/100
30/30             0s 8ms/step
Iteration 27 - Final Portfolio Value: 89.21265107383982, Accuracy:
0.2992623814541623, Hit Rate: 0.4934289127837515, Trades: 837
Running iteration 28/100
30/30             0s 8ms/step
Iteration 28 - Final Portfolio Value: 90.51500121148817, Accuracy:
0.30031612223393045, Hit Rate: 0.49760765550239233, Trades: 836
Running iteration 29/100
30/30             0s 8ms/step
Iteration 29 - Final Portfolio Value: 89.07908648380544, Accuracy:
0.2971548998946259, Hit Rate: 0.4929078014184397, Trades: 846
Running iteration 30/100
30/30             0s 8ms/step
Iteration 30 - Final Portfolio Value: 92.7927847513744, Accuracy:
0.2982086406743941, Hit Rate: 0.498812351543943, Trades: 842
Running iteration 31/100
30/30             0s 8ms/step
Iteration 31 - Final Portfolio Value: 93.95885846457969, Accuracy:
0.31612223393045313, Hit Rate: 0.4946236559139785, Trades: 744
Running iteration 32/100
30/30             0s 8ms/step
Iteration 32 - Final Portfolio Value: 92.94146512024477, Accuracy:
0.3119072708113804, Hit Rate: 0.4981226533166458, Trades: 799
Running iteration 33/100
30/30             0s 8ms/step
Iteration 33 - Final Portfolio Value: 90.22756870889671, Accuracy:
0.2971548998946259, Hit Rate: 0.49702734839476814, Trades: 841
Running iteration 34/100
30/30             0s 8ms/step
Iteration 34 - Final Portfolio Value: 88.51477178032044, Accuracy:
0.3171759747102213, Hit Rate: 0.4895977808599168, Trades: 721
Running iteration 35/100
30/30             0s 8ms/step
Iteration 35 - Final Portfolio Value: 89.24377406074007, Accuracy:
0.3055848261327713, Hit Rate: 0.4881889763779528, Trades: 762
Running iteration 36/100
30/30             0s 8ms/step
Iteration 36 - Final Portfolio Value: 86.0105724813331, Accuracy:
0.303477344573235, Hit Rate: 0.4938875305623472, Trades: 818
Running iteration 37/100
30/30             0s 8ms/step
Iteration 37 - Final Portfolio Value: 90.37577235744791, Accuracy:
0.3087460484720759, Hit Rate: 0.4913907284768212, Trades: 755
Running iteration 38/100
30/30             0s 8ms/step
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Iteration 38 - Final Portfolio Value: 88.58251712271735, Accuracy:
0.2950474183350896, Hit Rate: 0.49230769230769234, Trades: 845
Running iteration 39/100
30/30             0s 8ms/step
Iteration 39 - Final Portfolio Value: 86.5945197887194, Accuracy:
0.3066385669125395, Hit Rate: 0.48959608323133413, Trades: 817
Running iteration 40/100
30/30             0s 8ms/step
Iteration 40 - Final Portfolio Value: 86.76201093447125, Accuracy:
0.3076923076923077, Hit Rate: 0.4925373134328358, Trades: 804
Running iteration 41/100
30/30             0s 8ms/step
Iteration 41 - Final Portfolio Value: 92.16043080171326, Accuracy:
0.3055848261327713, Hit Rate: 0.4962686567164179, Trades: 804
Running iteration 42/100
30/30             0s 8ms/step
Iteration 42 - Final Portfolio Value: 93.56553873591972, Accuracy:
0.2992623814541623, Hit Rate: 0.4994110718492344, Trades: 849
Running iteration 43/100
30/30             0s 8ms/step
Iteration 43 - Final Portfolio Value: 87.12622278736359, Accuracy:
0.3087460484720759, Hit Rate: 0.4848084544253633, Trades: 757
Running iteration 44/100
30/30             0s 8ms/step
Iteration 44 - Final Portfolio Value: 89.14447773150906, Accuracy:
0.2992623814541623, Hit Rate: 0.49403341288782815, Trades: 838
Running iteration 45/100
30/30             0s 8ms/step
Iteration 45 - Final Portfolio Value: 86.1734209051225, Accuracy:
0.3055848261327713, Hit Rate: 0.4891994917407878, Trades: 787
Running iteration 46/100
30/30             0s 8ms/step
Iteration 46 - Final Portfolio Value: 88.13123896944018, Accuracy:
0.3150684931506849, Hit Rate: 0.49340369393139843, Trades: 758
Running iteration 47/100
30/30             0s 8ms/step
Iteration 47 - Final Portfolio Value: 100.57669048170305, Accuracy:
0.3055848261327713, Hit Rate: 0.5046838407494145, Trades: 854
Running iteration 48/100
30/30             0s 8ms/step
Iteration 48 - Final Portfolio Value: 89.42180427510866, Accuracy:
0.3087460484720759, Hit Rate: 0.4896373056994819, Trades: 772
Running iteration 49/100
30/30             0s 8ms/step
Iteration 49 - Final Portfolio Value: 88.9140105419784, Accuracy:
0.3076923076923077, Hit Rate: 0.4909560723514212, Trades: 774
Running iteration 50/100
30/30             0s 8ms/step
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Iteration 50 - Final Portfolio Value: 80.65352468731274, Accuracy:
0.2929399367755532, Hit Rate: 0.49029126213592233, Trades: 824
Running iteration 51/100
30/30             0s 8ms/step
Iteration 51 - Final Portfolio Value: 86.80858585375836, Accuracy:
0.3013698630136986, Hit Rate: 0.48941469489414696, Trades: 803
Running iteration 52/100
30/30             0s 8ms/step
Iteration 52 - Final Portfolio Value: 87.1844632920818, Accuracy:
0.3119072708113804, Hit Rate: 0.4873501997336884, Trades: 751
Running iteration 53/100
30/30             0s 8ms/step
Iteration 53 - Final Portfolio Value: 83.13043070472966, Accuracy:
0.3066385669125395, Hit Rate: 0.487468671679198, Trades: 798
Running iteration 54/100
30/30             0s 8ms/step
Iteration 54 - Final Portfolio Value: 94.99277044555774, Accuracy:
0.2950474183350896, Hit Rate: 0.5, Trades: 866
Running iteration 55/100
30/30             0s 8ms/step
Iteration 55 - Final Portfolio Value: 96.93971592226802, Accuracy:
0.303477344573235, Hit Rate: 0.4994124559341951, Trades: 851
Running iteration 56/100
30/30             0s 8ms/step
Iteration 56 - Final Portfolio Value: 90.34082939094165, Accuracy:
0.30031612223393045, Hit Rate: 0.49640287769784175, Trades: 834
Running iteration 57/100
30/30             0s 8ms/step
Iteration 57 - Final Portfolio Value: 89.08618240715762, Accuracy:
0.2971548998946259, Hit Rate: 0.4958968347010551, Trades: 853
Running iteration 58/100
30/30             0s 8ms/step
Iteration 58 - Final Portfolio Value: 93.31438518660445, Accuracy:
0.3013698630136986, Hit Rate: 0.49643705463182897, Trades: 842
Running iteration 59/100
30/30             0s 8ms/step
Iteration 59 - Final Portfolio Value: 85.42264248115856, Accuracy:
0.3066385669125395, Hit Rate: 0.48348745046235136, Trades: 757
Running iteration 60/100
30/30             0s 8ms/step
Iteration 60 - Final Portfolio Value: 90.46317352342209, Accuracy:
0.3055848261327713, Hit Rate: 0.49687108886107634, Trades: 799
Running iteration 61/100
30/30             0s 8ms/step
Iteration 61 - Final Portfolio Value: 92.33821426484974, Accuracy:
0.30979978925184404, Hit Rate: 0.4981132075471698, Trades: 795
Running iteration 62/100
30/30             0s 8ms/step
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Iteration 62 - Final Portfolio Value: 80.76553932083957, Accuracy:
0.2929399367755532, Hit Rate: 0.47783251231527096, Trades: 812
Running iteration 63/100
30/30             0s 8ms/step
Iteration 63 - Final Portfolio Value: 93.91954096408506, Accuracy:
0.30242360379346683, Hit Rate: 0.4975845410628019, Trades: 828
Running iteration 64/100
30/30             0s 8ms/step
Iteration 64 - Final Portfolio Value: 82.08611192239758, Accuracy:
0.2929399367755532, Hit Rate: 0.48588957055214727, Trades: 815
Running iteration 65/100
30/30             0s 8ms/step
Iteration 65 - Final Portfolio Value: 94.4865264605233, Accuracy:
0.30031612223393045, Hit Rate: 0.4982164090368609, Trades: 841
Running iteration 66/100
30/30             0s 8ms/step
Iteration 66 - Final Portfolio Value: 87.03661187249648, Accuracy:
0.3108535300316122, Hit Rate: 0.49246231155778897, Trades: 796
Running iteration 67/100
30/30             0s 8ms/step
Iteration 67 - Final Portfolio Value: 86.64660716443996, Accuracy:
0.30453108535300316, Hit Rate: 0.4899497487437186, Trades: 796
Running iteration 68/100
30/30             0s 8ms/step
Iteration 68 - Final Portfolio Value: 90.91517373270926, Accuracy:
0.3150684931506849, Hit Rate: 0.49603174603174605, Trades: 756
Running iteration 69/100
30/30             0s 8ms/step
Iteration 69 - Final Portfolio Value: 80.1804396173882, Accuracy:
0.30242360379346683, Hit Rate: 0.47766749379652607, Trades: 806
Running iteration 70/100
30/30             0s 8ms/step
Iteration 70 - Final Portfolio Value: 93.15839500801292, Accuracy:
0.2992623814541623, Hit Rate: 0.49463647199046484, Trades: 839
Running iteration 71/100
30/30             0s 8ms/step
Iteration 71 - Final Portfolio Value: 96.66234900150187, Accuracy:
0.30031612223393045, Hit Rate: 0.5, Trades: 878
Running iteration 72/100
30/30             0s 8ms/step
Iteration 72 - Final Portfolio Value: 91.85198897079061, Accuracy:
0.3013698630136986, Hit Rate: 0.5005959475566151, Trades: 839
Running iteration 73/100
30/30             0s 8ms/step
Iteration 73 - Final Portfolio Value: 96.66215406864586, Accuracy:
0.3055848261327713, Hit Rate: 0.4988066825775656, Trades: 838
Running iteration 74/100
30/30             0s 8ms/step
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Iteration 74 - Final Portfolio Value: 88.5846826330656, Accuracy:
0.3076923076923077, Hit Rate: 0.4949238578680203, Trades: 788
Running iteration 75/100
30/30             0s 8ms/step
Iteration 75 - Final Portfolio Value: 96.78170846784536, Accuracy:
0.2982086406743941, Hit Rate: 0.4988532110091743, Trades: 872
Running iteration 76/100
30/30             0s 8ms/step
Iteration 76 - Final Portfolio Value: 89.33749580055593, Accuracy:
0.3055848261327713, Hit Rate: 0.4981549815498155, Trades: 813
Running iteration 77/100
30/30             0s 8ms/step
Iteration 77 - Final Portfolio Value: 86.77231660256064, Accuracy:
0.30453108535300316, Hit Rate: 0.4919852034525277, Trades: 811
Running iteration 78/100
30/30             0s 8ms/step
Iteration 78 - Final Portfolio Value: 88.5939623669014, Accuracy:
0.3108535300316122, Hit Rate: 0.4934210526315789, Trades: 760
Running iteration 79/100
30/30             0s 8ms/step
Iteration 79 - Final Portfolio Value: 98.00322000943885, Accuracy:
0.30453108535300316, Hit Rate: 0.502944640753828, Trades: 849
Running iteration 80/100
30/30             0s 8ms/step
Iteration 80 - Final Portfolio Value: 90.43540486610559, Accuracy:
0.3013698630136986, Hit Rate: 0.49514563106796117, Trades: 824
Running iteration 81/100
30/30             0s 8ms/step
Iteration 81 - Final Portfolio Value: 94.70944633603037, Accuracy:
0.2992623814541623, Hit Rate: 0.5, Trades: 852
Running iteration 82/100
30/30             0s 8ms/step
Iteration 82 - Final Portfolio Value: 84.34550387706872, Accuracy:
0.2950474183350896, Hit Rate: 0.49466192170818507, Trades: 843
Running iteration 83/100
30/30             0s 8ms/step
Iteration 83 - Final Portfolio Value: 85.88060804179585, Accuracy:
0.30979978925184404, Hit Rate: 0.48677248677248675, Trades: 756
Running iteration 84/100
30/30             0s 8ms/step
Iteration 84 - Final Portfolio Value: 89.59980498070107, Accuracy:
0.29610115911485774, Hit Rate: 0.4946492271105826, Trades: 841
Running iteration 85/100
30/30             0s 8ms/step
Iteration 85 - Final Portfolio Value: 83.18597847506695, Accuracy:
0.2992623814541623, Hit Rate: 0.4836683417085427, Trades: 796
Running iteration 86/100
30/30             0s 8ms/step
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Iteration 86 - Final Portfolio Value: 83.36050879448962, Accuracy:
0.30242360379346683, Hit Rate: 0.4791929382093317, Trades: 793
Running iteration 87/100
30/30             0s 8ms/step
Iteration 87 - Final Portfolio Value: 94.42833823191162, Accuracy:
0.30031612223393045, Hit Rate: 0.500587544065805, Trades: 851
Running iteration 88/100
30/30             0s 8ms/step
Iteration 88 - Final Portfolio Value: 97.03035375192698, Accuracy:
0.2992623814541623, Hit Rate: 0.4970896391152503, Trades: 859
Running iteration 89/100
30/30             0s 8ms/step
Iteration 89 - Final Portfolio Value: 90.95153560760988, Accuracy:
0.29610115911485774, Hit Rate: 0.4946871310507674, Trades: 847
Running iteration 90/100
30/30             0s 8ms/step
Iteration 90 - Final Portfolio Value: 87.21469419084397, Accuracy:
0.303477344573235, Hit Rate: 0.4921212121212121, Trades: 825
Running iteration 91/100
30/30             1s 10ms/step
Iteration 91 - Final Portfolio Value: 100.36478369982314, Accuracy:
0.2992623814541623, Hit Rate: 0.5087310826542492, Trades: 859
Running iteration 92/100
30/30             0s 9ms/step
Iteration 92 - Final Portfolio Value: 87.72712706959271, Accuracy:
0.30979978925184404, Hit Rate: 0.49433962264150944, Trades: 795
Running iteration 93/100
30/30             0s 9ms/step
Iteration 93 - Final Portfolio Value: 87.60635838729635, Accuracy:
0.2992623814541623, Hit Rate: 0.49524940617577196, Trades: 842
Running iteration 94/100
30/30             0s 8ms/step
Iteration 94 - Final Portfolio Value: 82.67281117122099, Accuracy:
0.3066385669125395, Hit Rate: 0.48564294631710364, Trades: 801
Running iteration 95/100
30/30             0s 8ms/step
Iteration 95 - Final Portfolio Value: 87.65668202282566, Accuracy:
0.2929399367755532, Hit Rate: 0.48933649289099523, Trades: 844
Running iteration 96/100
30/30             0s 8ms/step
Iteration 96 - Final Portfolio Value: 95.24576119468057, Accuracy:
0.30031612223393045, Hit Rate: 0.49644549763033174, Trades: 844
Running iteration 97/100
30/30             0s 9ms/step
Iteration 97 - Final Portfolio Value: 85.8900430017944, Accuracy:
0.3055848261327713, Hit Rate: 0.48894348894348894, Trades: 814
Running iteration 98/100
30/30             0s 8ms/step
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Iteration 98 - Final Portfolio Value: 89.35677971048128, Accuracy:
0.3066385669125395, Hit Rate: 0.49433962264150944, Trades: 795
Running iteration 99/100
30/30             0s 8ms/step
Iteration 99 - Final Portfolio Value: 84.33884163774044, Accuracy:
0.303477344573235, Hit Rate: 0.4819121447028424, Trades: 774
Running iteration 100/100
30/30             0s 8ms/step
Iteration 100 - Final Portfolio Value: 91.07360418592569, Accuracy:
0.31401475237091675, Hit Rate: 0.49809885931558934, Trades: 789
Average Final Portfolio Value:
89.7758879889213
Standard Deviation of Final Values:
4.61491539406169
Average Accuracy:
0.3045626975763962
Average Hit Rate:
0.49368217695086647
Average No. of Trades:
809.6
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