Exercise 2.2: Complex machine learning models
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Model: CNN

I chose CNN for this analysis because although the data involves a time component, the current analysis disregards that component. CNN is more appropriate because it can handle the complexity of the data.

Version 1:

Starting Hyperparameters:

```
epochs = 5
batch_size = 16
n_hidden = 4

timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = len(y_train[0])

model = Sequential()
model.add(Conv1D(n_hidden, kernel_size=2, activation='relu', input_shape=(timesteps, input_dim)))
model.add(Dense(16, activation='relu'))
model.add(MaxPooling1D())
model.add(Flatten())
model.add(Dense(n_classes, activation='softmax')) # Options: sigmoid, tanh, softmax, relu
```

Initial Confusion Matrix:

```
144/144 ━━━━━━━━━━━━━━━━━━━━ 0s 2ms/step
Pred        DEBILT  HEATHROW  KASSEL  LJUBLJANA  MAASTRICHT  MADRID  OSLO  \
True
BASEL          102        79       9         25           2     239     5
BELGRADE         0         0       0          0           4       9     0
BUDAPEST         0         0       0          0           0       2     0
DEBILT           0         0       0          0           0       0     0
DUSSELDORF       0         0       0          0           0       0     0
HEATHROW         0         0       0          0           0       1     0
KASSEL           0         0       0          0           0       0     0
LJUBLJANA        0         0       0          0           0       0     0
MAASTRICHT       0         0       0          0           0       0     0
MADRID           0         0       0          0           0      27     0
MUNCHENB         0         0       0          0           0       0     0
OSLO             0         0       0          0           0       0     0
STOCKHOLM        0         0       0          0           0       0     0
VALENTIA         0         0       0          0           0       0     0

Pred        STOCKHOLM
True
BASEL            2507
BELGRADE          844
BUDAPEST          191
DEBILT             72
DUSSELDORF         25
HEATHROW           69
KASSEL              7
LJUBLJANA          30
MAASTRICHT          8
MADRID            321
MUNCHENB            4
OSLO                6
STOCKHOLM           1
VALENTIA            1
```

8 stations, accuracy 11%, loss 785,503

Version 2:

Hyperparameters:

```
epochs = 20
batch_size = 25
n_hidden = 8

timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = len(y_train[0])

model = Sequential()
model.add(Conv1D(n_hidden, kernel_size=2, activation='relu', input_shape=(timesteps, input_dim)))
model.add(Dense(16, activation='relu'))
model.add(MaxPooling1D())
model.add(Flatten())
model.add(Dense(n_classes, activation='softmax')) # Options: sigmoid, tanh, softmax, relu
```

Confusion Matrix:

```
144/144 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step
Pred        BASEL  BELGRADE  BUDAPEST  DEBILT  HEATHROW  KASSEL  LJUBLJANA  \
True
BASEL         143        82       158     107        38      40        453
BELGRADE        0         3       132       4         0       0        137
BUDAPEST        1         0        25       6         0       0         28
DEBILT          1         0         2       3         0       0          5
DUSSELDORF      0         0         1       0         0       0          2
HEATHROW        0         0         9       1         0       0         11
KASSEL          0         0         0       0         0       0          1
LJUBLJANA       0         0         2       0         0       0         19
MAASTRICHT      0         0         0       0         0       0          1
MADRID         25         1        63      17         0       0         82
MUNCHENB        0         0         2       0         0       0          2
OSLO            0         0         1       0         0       0          1
STOCKHOLM       0         0         0       0         0       0          1
VALENTIA        0         0         0       0         0       0          0

Pred        MAASTRICHT  MUNCHENB  OSLO  SONNBLICK  STOCKHOLM  VALENTIA
True
BASEL               11      1844    42          6         18        26
BELGRADE             0       581     0          0          0         0
BUDAPEST             0       133     0          0          0         0
DEBILT               0        61     0          0          0         0
DUSSELDORF           0        22     0          0          0         0
HEATHROW             0        49     0          0          0         0
KASSEL               0         6     0          0          0         0
LJUBLJANA            0         9     0          0          0         0
MAASTRICHT           0         7     0          0          0         0
MADRID               0       156     2          0          2         0
MUNCHENB             0         0     0          0          0         0
OSLO                 0         4     0          0          0         0
STOCKHOLM            0         0     0          0          0         0
VALENTIA             0         1     0          0          0         0
```

13 stations, accuracy 12.8%, loss 2,165,907

Version 3:

Hyperparameters:

```
epochs = 30
batch_size = 25
n_hidden = 16

timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = len(y_train[0])

model = Sequential()
model.add(Conv1D(n_hidden, kernel_size=2, activation='relu', input_shape=(timesteps, input_dim)))
model.add(Dense(16, activation='relu'))
model.add(MaxPooling1D())
model.add(Flatten())
model.add(Dense(n_classes, activation='softmax')) # Options: sigmoid, tanh, softmax, relu
```

Confusion matrix:

```
144/144 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step
Pred        BASEL  BELGRADE  BUDAPEST  DEBILT  DUSSELDORF  KASSEL  LJUBLJANA  \
True
BASEL        1458        49        85     334          22       3        311
BELGRADE      286         0         3      25           0       0        217
BUDAPEST       73         0         1      12           0       0         39
DEBILT         31         0         0      10           0       0         13
DUSSELDORF     13         0         0       6           0       0          2
HEATHROW       32         0         0       8           0       0          2
KASSEL          4         0         0       1           0       0          1
LJUBLJANA      13         0         0       2           0       0          5
MAASTRICHT      8         0         0       0           0       0          0
MADRID        164         0         0      46           0       0         40
MUNCHENB        0         0         0       0           0       0          4
OSLO            0         0         0       1           0       0          1
STOCKHOLM       0         0         0       0           0       0          1
VALENTIA        1         0         0       0           0       0          0

Pred        MADRID  MUNCHENB  OSLO  SONNBLICK  STOCKHOLM  VALENTIA
True
BASEL          208       413    38          6         12        29
BELGRADE       135       190     1          0          0         0
BUDAPEST        41        26     1          0          0         0
DEBILT          10         7     1          0          0         0
DUSSELDORF       3         1     0          0          0         0
HEATHROW        26         2     0          0          0         0
KASSEL           0         1     0          0          0         0
LJUBLJANA       10         0     0          0          0         0
MAASTRICHT       0         0     0          0          0         0
MADRID          87         2     7          0          2         0
MUNCHENB         0         0     0          0          0         0
OSLO             3         1     0          0          0         0
STOCKHOLM        0         0     0          0          0         0
VALENTIA         0         0     0          0          0         0
```

13 stations, accuracy 11.6%, loss 10,374,783

*Loss is increasing exponentially. We will need to change the activation type for v4.*

Version 4:

Hyperparameters:

```
epochs = 30
batch_size = 30
n_hidden = 64

timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = len(y_train[0])

model = Sequential()
model.add(Conv1D(n_hidden, kernel_size=2, activation='sigmoid', input_shape=(timesteps, input_dim)))
model.add(Dense(16, activation='sigmoid'))
model.add(MaxPooling1D())
model.add(Flatten())
model.add(Dense(n_classes, activation='relu')) # Options: sigmoid, tanh, softmax, relu
```

Confusion matrix:

```
144/144 ━━━━━━━━━━━━━━━━━━━━ 1s 6ms/step
Pred         BASEL
True
BASEL         2968
BELGRADE       857
BUDAPEST       193
DEBILT          72
DUSSELDORF      25
HEATHROW        70
KASSEL           7
LJUBLJANA       30
MAASTRICHT       8
MADRID         348
MUNCHENB         4
OSLO             6
STOCKHOLM        1
VALENTIA         1
```

*Well, that's not going to work. Accuracy is 64% and loss is nan, but it only found one station. Let's try one more time.*

Version 4

Hyperparameters:

```
epochs = 30
batch_size = 16
n_hidden = 256

timesteps = len(X_train[0])
input_dim = len(X_train[0][0])
n_classes = len(y_train[0])

model = Sequential()
model.add(Conv1D(n_hidden, kernel_size=2, activation='tanh', input_shape=(timesteps, input_dim)))
model.add(Dense(16, activation='tanh'))
model.add(MaxPooling1D())
model.add(Flatten())
model.add(Dense(n_classes, activation='softmax')) # Options: sigmoid, tanh, softmax, relu
```

Confusion Matrix:

```
144/144 ━━━━━━━━━━━━━━━━━━━━ 1s 8ms/step
Pred        BASEL  BELGRADE  BUDAPEST  DEBILT  DUSSELDORF  HEATHROW  KASSEL  \
True
BASEL           3       204        39      15          39        48     141
BELGRADE        0       118        19       0           0         0       0
BUDAPEST        0        10         5       0           0         0       0
DEBILT          0         1         3       0           0         0       0
DUSSELDORF      0         0         0       0           0         0       0
HEATHROW        0         0         0       1           0         1       0
KASSEL          0         2         0       0           0         0       0
LJUBLJANA       0         3         0       0           0         0       0
MAASTRICHT      0         0         0       0           0         0       0
MADRID          0         3         0       0           0         1       0
MUNCHENB        0         0         1       0           0         0       0
OSLO            0         0         0       0           0         0       0
STOCKHOLM       0         1         0       0           0         0       0
VALENTIA        0         0         0       0           0         0       0

Pred        LJUBLJANA  MAASTRICHT  MADRID  MUNCHENB  OSLO  SONNBLICK  \
True
BASEL              15          24    1365         2    87         63
BELGRADE            3           0     716         1     0          0
BUDAPEST            1           0     177         0     0          0
DEBILT              0           0      68         0     0          0
DUSSELDORF          0           0      25         0     0          0
HEATHROW            0           0      68         0     0          0
KASSEL              0           0       5         0     0          0
LJUBLJANA           0           0      27         0     0          0
MAASTRICHT          0           0       7         1     0          0
MADRID              0           0     342         0     0          2
MUNCHENB            0           0       2         1     0          0
OSLO                0           0       6         0     0          0
STOCKHOLM           0           0       0         0     0          0
VALENTIA            0           0       1         0     0          0

Pred        STOCKHOLM  VALENTIA
True
BASEL             102       821
BELGRADE            0         0
BUDAPEST            0         0
DEBILT              0         0
DUSSELDORF          0         0
HEATHROW            0         0
KASSEL              0         0
LJUBLJANA           0         0
MAASTRICHT          0         0
MADRID              0         0
MUNCHENB            0         0
OSLO                0         0
STOCKHOLM           0         0
VALENTIA            0         0
```

The model now recognizes all 15 stations, with 10.4% accuracy and loss of 40.7