Time Series Prediction with LSTM Using PyTorch

Library

In [111…

```
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import torch
import torch.nn as nn
from torch.autograd import Variable
from sklearn.preprocessing import MinMaxScaler
```

Part I: Atlanta Violent Crime

In [114…

```
df = pd.read_csv('atl_violent_final_v2.csv').rename(columns={"Unnamed: 0": "Date",
                                                             "occurance_count": "Crime"})
df
```

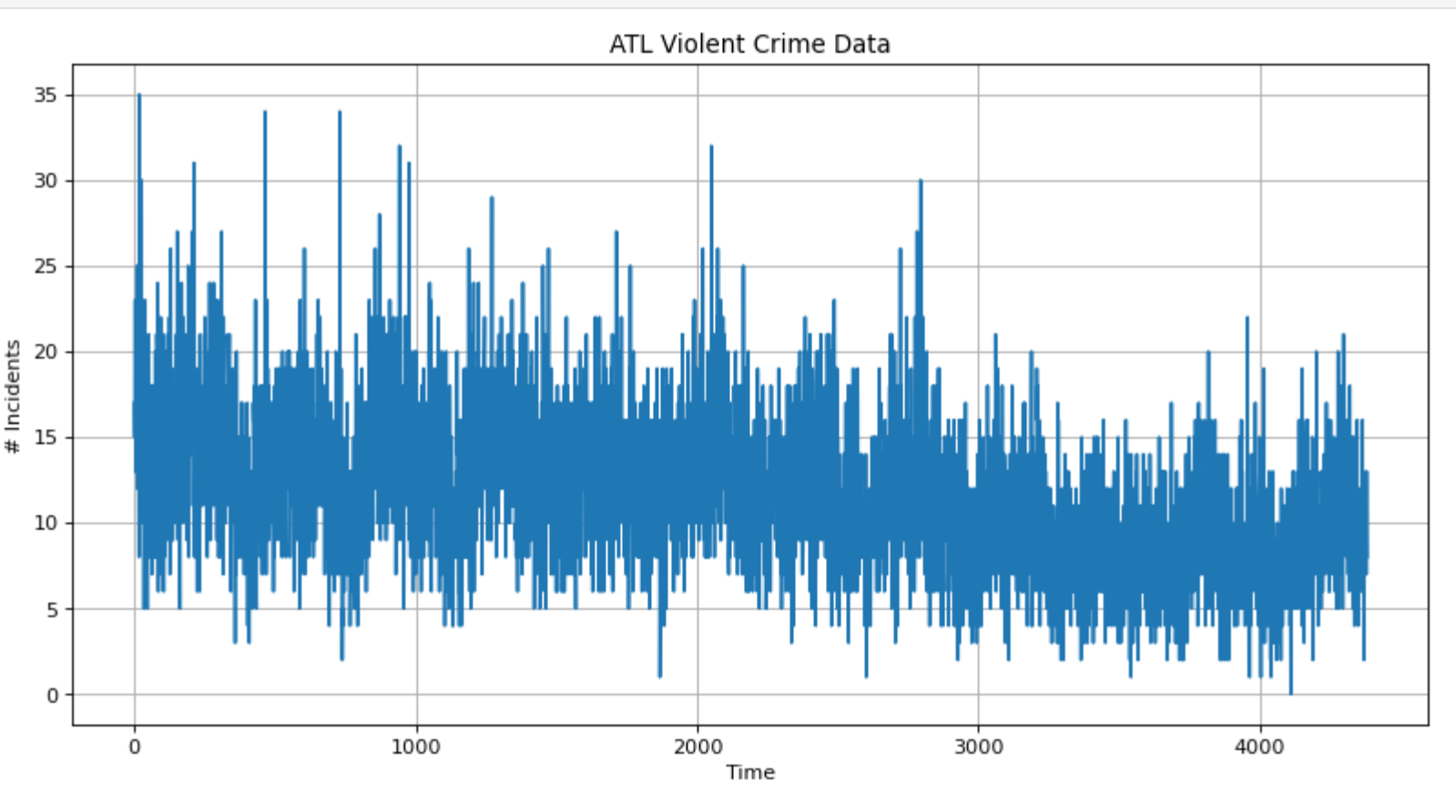
Out[114…

	Date	Crime
0	1/1/2009	17
1	1/2/2009	15
2	1/3/2009	23
3	1/4/2009	23
4	1/5/2009	13
...	...	...
4378	12/27/2020	11
4379	12/28/2020	8
4380	12/29/2020	7
4381	12/30/2020	13
4382	12/31/2020	8

4383 rows × 2 columns

In [115…

```
training_set = df.iloc[:,1:2].values

plt.figure(figsize=(12, 6), dpi=80)

plt.plot(training_set)
plt.grid(True)
plt.ylabel('# Incidents')
plt.xlabel('Time')
plt.title('ATL Violent Crime Data')
plt.show()
```



Dataloading

In [116…

```
def sliding_windows(data, seq_length):
    x = []
    y = []

    for i in range(len(data)-seq_length-1):
        _x = data[i:(i+seq_length)]
        _y = data[i+seq_length]
        x.append(_x)
        y.append(_y)

    return np.array(x), np.array(y)

sc = MinMaxScaler()
training_data = sc.fit_transform(training_set)

seq_length = 7
x, y = sliding_windows(training_data, seq_length)

test_size = 7                   #len(y) - train_size
train_size = len(y) - test_size #int(len(y) * 0.67)

dataX = Variable(torch.Tensor(np.array(x)))
dataY = Variable(torch.Tensor(np.array(y)))

trainX = Variable(torch.Tensor(np.array(x[0:train_size])))
trainY = Variable(torch.Tensor(np.array(y[0:train_size])))

testX = Variable(torch.Tensor(np.array(x[train_size:len(x)])))
testY = Variable(torch.Tensor(np.array(y[train_size:len(y)])))
```

Model

In [117…

```
class LSTM(nn.Module):

    def __init__(self, num_classes, input_size, hidden_size, num_layers):
        super(LSTM, self).__init__()

        self.num_classes = num_classes
        self.num_layers = num_layers
        self.input_size = input_size
        self.hidden_size = hidden_size
        self.seq_length = seq_length

        self.lstm = nn.LSTM(input_size=input_size, hidden_size=hidden_size,
                            num_layers=num_layers, batch_first=True)

        self.fc = nn.Linear(hidden_size, num_classes)

    def forward(self, x):
        h_0 = Variable(torch.zeros(
            self.num_layers, x.size(0), self.hidden_size))

        c_0 = Variable(torch.zeros(
            self.num_layers, x.size(0), self.hidden_size))

        # Propagate input through LSTM
        ula, (h_out, _) = self.lstm(x, (h_0, c_0))

        h_out = h_out.view(-1, self.hidden_size)

        out = self.fc(h_out)

        return out
```

Training

In [118…

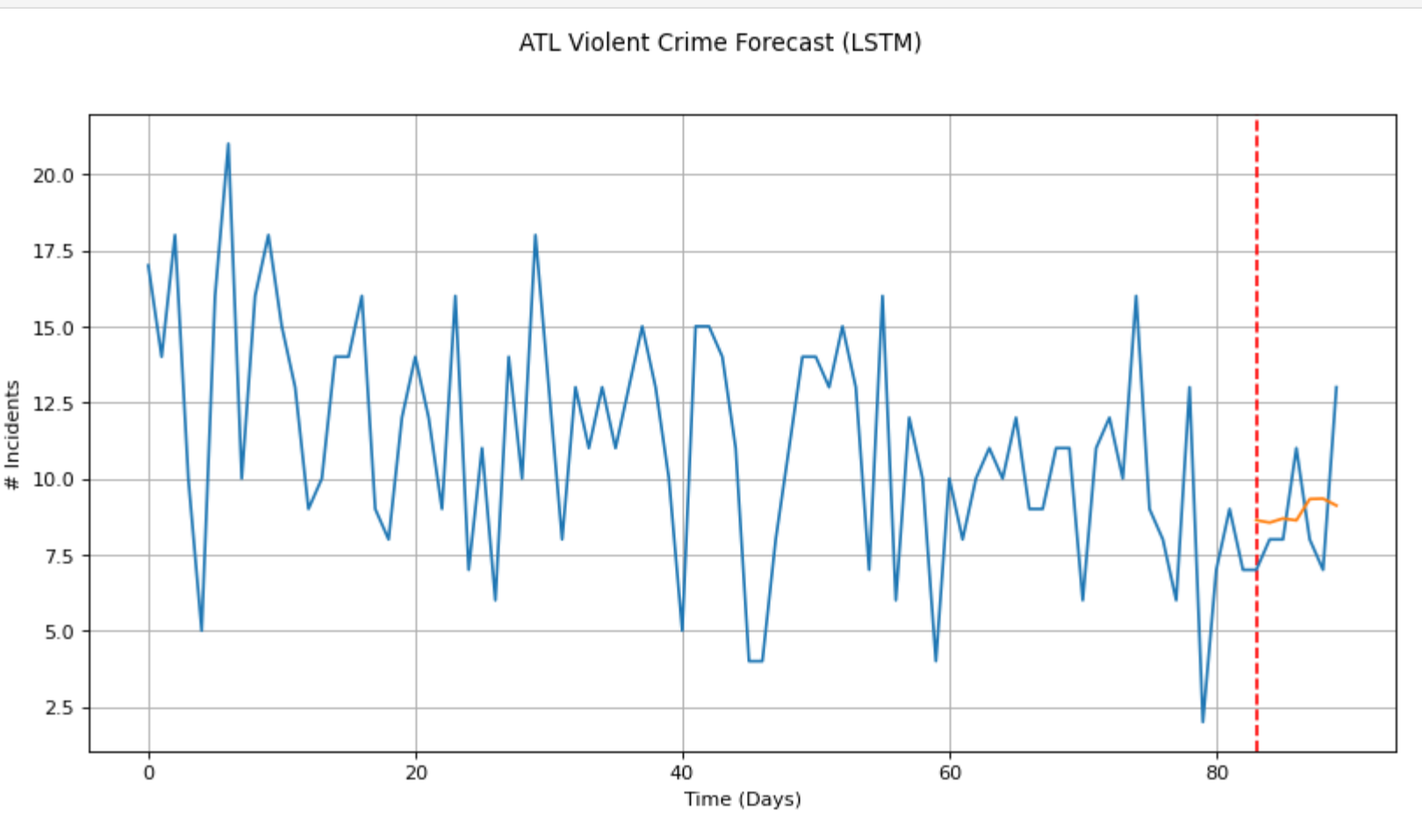
```
num_epochs = 300
learning_rate = 0.01

input_size = 1
hidden_size = 2
num_layers = 1

num_classes = 1

lstm = LSTM(num_classes, input_size, hidden_size, num_layers)

criterion = torch.nn.MSELoss()    # mean-squared error for regression
optimizer = torch.optim.Adam(lstm.parameters(), lr=learning_rate)
#optimizer = torch.optim.SGD(lstm.parameters(), lr=learning_rate)

# Train the model
for epoch in range(num_epochs):
    outputs = lstm(trainX)
    optimizer.zero_grad()

    # obtain the loss function
    loss = criterion(outputs, trainY)

    loss.backward()

    optimizer.step()
    if epoch % 50 == 0:
        print("Epoch: %d, loss: %1.5f" % (epoch, loss.item()))
```

```
Epoch: 0, loss: 0.08530
Epoch: 50, loss: 0.01567
Epoch: 100, loss: 0.01482
Epoch: 150, loss: 0.01384
Epoch: 200, loss: 0.01311
Epoch: 250, loss: 0.01302
```

Model Prediction & Forecasting

In [119…

```
lstm.eval()
train_predict = lstm(dataX)

data_predict = train_predict.data.numpy()
dataY_plot = dataY.data.numpy()

data_predict = sc.inverse_transform(data_predict)
dataY_plot = sc.inverse_transform(dataY_plot)


plt.figure(figsize=(12, 6), dpi=80)

size = 90
plt.axvline(x=size-test_size, c='r', linestyle='--')

x = np.arange(size-test_size, size, 1)

plt.plot(dataY_plot[-size:])
plt.plot(x, data_predict[-test_size:])
plt.suptitle('ATL Violent Crime Forecast (LSTM)')
plt.grid(True)
plt.ylabel('# Incidents')
plt.xlabel('Time (Days)')
plt.show()
```



Model Evaluation

In [120…

```
def mape(y_true, y_pred):
    temp = [abs(y_true[i]-y_pred[i])/y_true[i] for i in range(len(y_true)) if y_true[i] != 0]
    return np.mean(temp)

def pm(y_true, y_pred):
    return sum((y_true-y_pred)**2)/sum((y_true-np.mean(y_true))**2)

n = len(dataY_plot)
y_true = dataY_plot.reshape(n, )
y_pred = data_predict.reshape(n, )

mape = mape(y_true, y_pred)
pm = pm(y_true, y_pred)

print("==== Training Evaluation Metrics ====")
print("MAPE: {:.3f} \nPM:   {:.3f}".format(mape, pm))
```

```
==== Training Evaluation Metrics ====
MAPE: 0.351
PM:   0.792
```

In [121…

```
mape_test = np.mean(abs(y_true[train_size:len(y)]-y_pred[train_size:len(y)])/y_true[train_size:len(y)])
pm_test = sum((y_true[train_size:len(y)]-y_pred[train_size:len(y)])**2)/sum((y_true[train_size:len(y)]-np.mean

print("==== Test Evaluation Metrics ====")
print("MAPE: {:.3f} \nPM:   {:.3f}".format(mape_test, pm_test))
```

```
==== Test Evaluation Metrics ====
MAPE: 0.200
PM:   1.018
```

Part II: NYC Violent Crime

In [131…

```
df = pd.read_csv('nyc_violent_final_v3.csv').rename(columns={"Unnamed: 0": "Date",
                                                             "occurance_count": "Crime"})
df
```

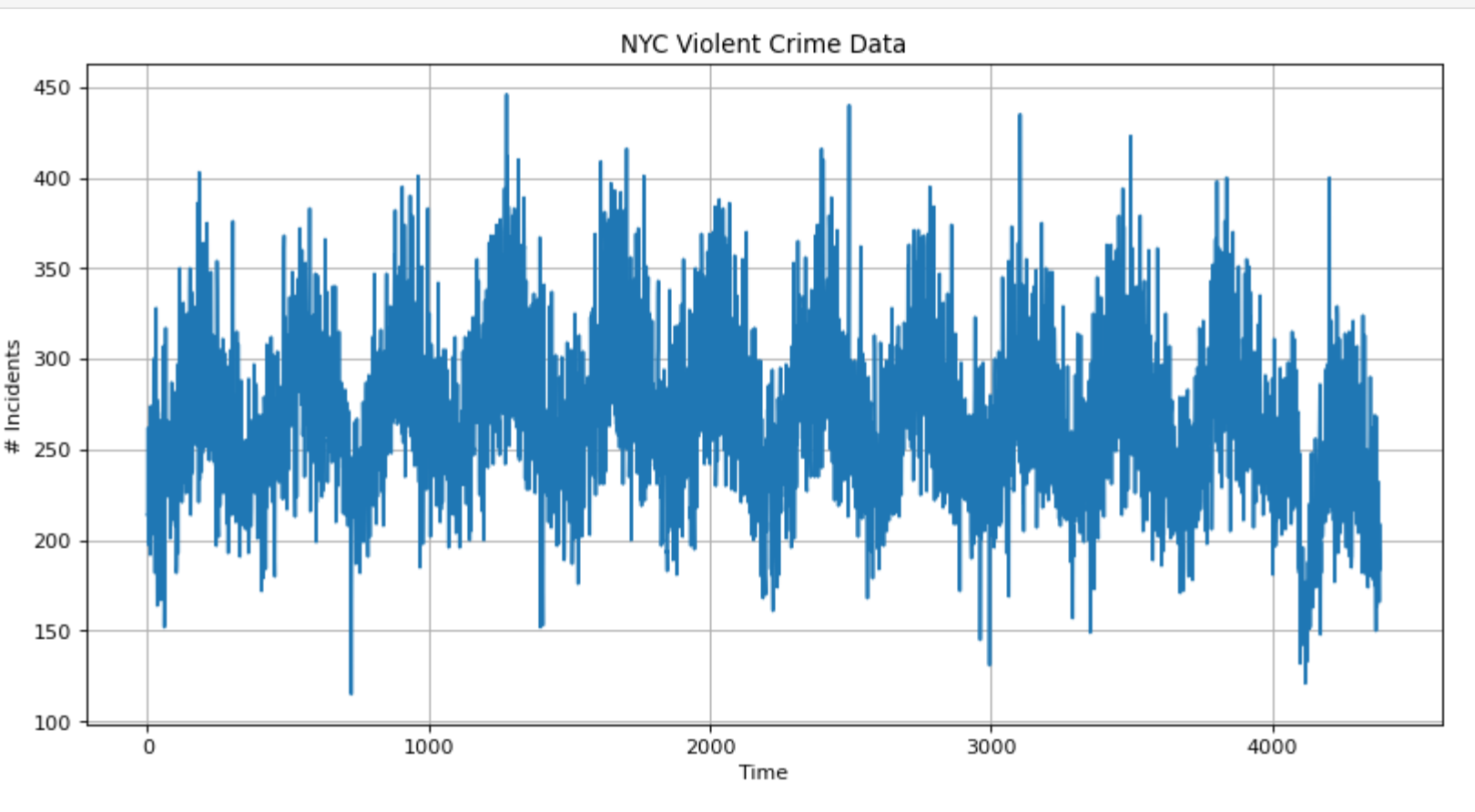
Out[131…

	Date	Crime
0	1/1/2009	214
1	1/2/2009	214
2	1/3/2009	262
3	1/4/2009	203
4	1/5/2009	220
...	...	...
4378	12/27/2020	196
4379	12/28/2020	185
4380	12/29/2020	166
4381	12/30/2020	209
4382	12/31/2020	184

4383 rows × 2 columns

In [204…

```
training_set = df.iloc[:,1:2].values

plt.figure(figsize=(12, 6), dpi=80)

plt.plot(training_set)
plt.grid(True)
plt.ylabel('# Incidents')
plt.xlabel('Time')
plt.title('NYC Violent Crime Data')
plt.show()
```



In [205…

```
def sliding_windows(data, seq_length):
    x = []
    y = []

    for i in range(len(data)-seq_length-1):
        _x = data[i:(i+seq_length)]
        _y = data[i+seq_length]
        x.append(_x)
        y.append(_y)

    return np.array(x), np.array(y)

sc = MinMaxScaler()
training_data = sc.fit_transform(training_set)

seq_length = 7
x, y = sliding_windows(training_data, seq_length)

test_size = 7                   #len(y) - train_size
train_size = len(y) - test_size #int(len(y) * 0.67)

dataX = Variable(torch.Tensor(np.array(x)))
dataY = Variable(torch.Tensor(np.array(y)))

trainX = Variable(torch.Tensor(np.array(x[0:train_size])))
trainY = Variable(torch.Tensor(np.array(y[0:train_size])))

testX = Variable(torch.Tensor(np.array(x[train_size:len(x)])))
testY = Variable(torch.Tensor(np.array(y[train_size:len(y)])))
```

Model

In [206…

```
class LSTM(nn.Module):

    def __init__(self, num_classes, input_size, hidden_size, num_layers):
        super(LSTM, self).__init__()

        self.num_classes = num_classes
        self.num_layers = num_layers
        self.input_size = input_size
        self.hidden_size = hidden_size
        self.seq_length = seq_length

        self.lstm = nn.LSTM(input_size=input_size, hidden_size=hidden_size,
                            num_layers=num_layers, batch_first=True)

        self.fc = nn.Linear(hidden_size, num_classes)

    def forward(self, x):
        h_0 = Variable(torch.zeros(
            self.num_layers, x.size(0), self.hidden_size))

        c_0 = Variable(torch.zeros(
            self.num_layers, x.size(0), self.hidden_size))

        # Propagate input through LSTM
        ula, (h_out, _) = self.lstm(x, (h_0, c_0))

        h_out = h_out.view(-1, self.hidden_size)

        out = self.fc(h_out)

        return out
```

Training

In [207…

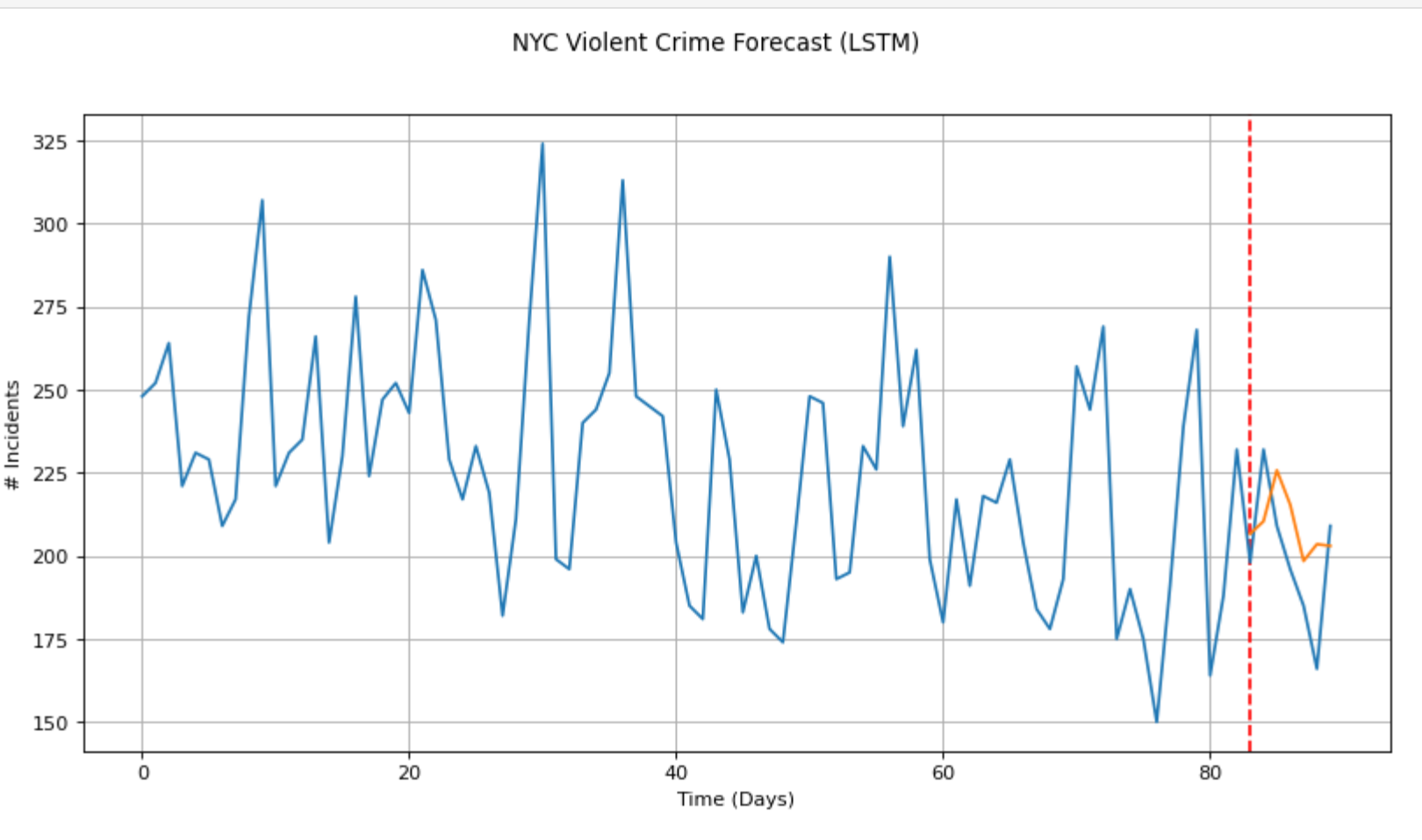
```
num_epochs = 300
learning_rate = 0.01

input_size = 1
hidden_size = 2
num_layers = 1

num_classes = 1

lstm = LSTM(num_classes, input_size, hidden_size, num_layers)

criterion = torch.nn.MSELoss()    # mean-squared error for regression
optimizer = torch.optim.Adam(lstm.parameters(), lr=learning_rate)
#optimizer = torch.optim.SGD(lstm.parameters(), lr=learning_rate)

# Train the model
for epoch in range(num_epochs):
    outputs = lstm(trainX)
    optimizer.zero_grad()

    # obtain the loss function
    loss = criterion(outputs, trainY)

    loss.backward()

    optimizer.step()
    if epoch % 50 == 0:
        print("Epoch: %d, loss: %1.5f" % (epoch, loss.item()))
```

```
Epoch: 0, loss: 0.03256
Epoch: 50, loss: 0.01570
Epoch: 100, loss: 0.01373
Epoch: 150, loss: 0.01255
Epoch: 200, loss: 0.01160
Epoch: 250, loss: 0.01086
```

Model Evaluation

In [208…

```
lstm.eval()
train_predict = lstm(dataX)

data_predict = train_predict.data.numpy()
dataY_plot = dataY.data.numpy()

data_predict = sc.inverse_transform(data_predict)
dataY_plot = sc.inverse_transform(dataY_plot)


plt.figure(figsize=(12, 6), dpi=80)

size = 90
plt.axvline(x=size-test_size, c='r', linestyle='--')

x = np.arange(size-test_size, size, 1)

plt.plot(dataY_plot[-size:])
plt.plot(x, data_predict[-test_size:])
plt.suptitle('NYC Violent Crime Forecast (LSTM)')
plt.grid(True)
plt.ylabel('# Incidents')
plt.xlabel('Time (Days)')
plt.show()
```



Model Evaluation

In [209…

```
def mape(y_true, y_pred):
    temp = [abs(y_true[i]-y_pred[i])/y_true[i] for i in range(len(y_true)) if y_true[i] != 0]
    return np.mean(temp)

def pm(y_true, y_pred):
    return sum((y_true-y_pred)**2)/sum((y_true-np.mean(y_true))**2)

n = len(dataY_plot)
y_true = dataY_plot.reshape(n, )
y_pred = data_predict.reshape(n, )

mape = mape(y_true, y_pred)
pm = pm(y_true, y_pred)

print("==== Training Evaluation Metrics ====")
print("MAPE: {:.3f} \nPM:   {:.3f}".format(mape, pm))
```

```
==== Training Evaluation Metrics ====
MAPE: 0.101
PM:   0.583
```

In [210…

```
mape_test = np.mean(abs(y_true[train_size:len(y)]-y_pred[train_size:len(y)])/y_true[train_size:len(y)])
pm_test = sum((y_true[train_size:len(y)]-y_pred[train_size:len(y)])**2)/sum((y_true[train_size:len(y)]-np.mean

print("==== Test Evaluation Metrics ====")
print("MAPE: {:.3f} \nPM:   {:.3f}".format(mape_test, pm_test))
```

```
==== Test Evaluation Metrics ====
MAPE: 0.092
PM:   1.093
```