```
import keras
keras.__version__
```

```
'2.4.3'
```

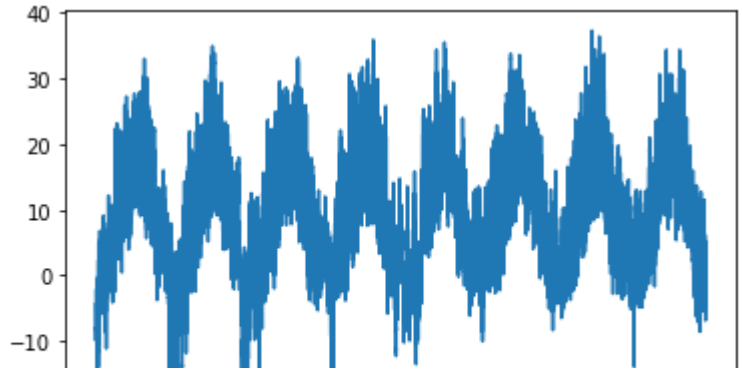
```
from google.colab import drive
drive.mount('/content/gdrive')
```

```
Mounted at /content/gdrive
```

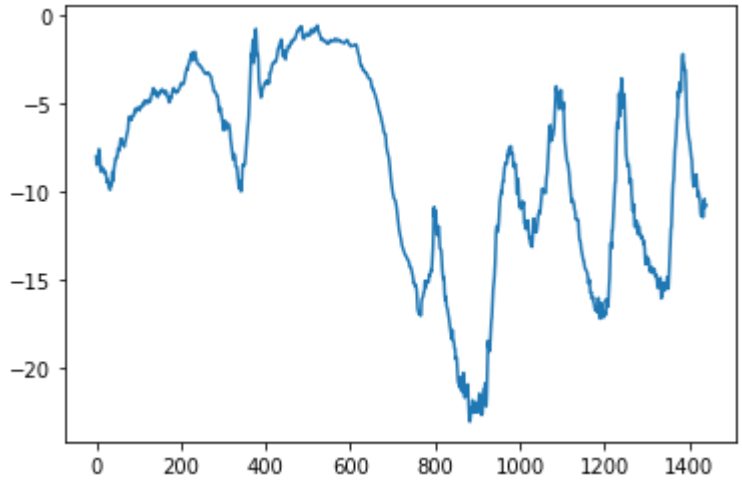
```
import os

data_dir = '/content/gdrive/MyDrive/ML Assignment 4'
fname = os.path.join(data_dir, 'jena_climate_2009_2016.csv')


f = open(fname)
data = f.read()
f.close()

lines = data.split('\n')
header = lines[0].split(',')
lines = lines[1:]

print(header)
print(len(lines))
```

```
['"Date Time"', '"p (mbar)"', '"T (degC)"', '"Tpot (K)"', '"Tdew (degC)"', '"rh (%)"',
420551
```

```
import numpy as np

float_data = np.zeros((len(lines), len(header) - 1))
for i, line in enumerate(lines):
    values = [float(x) for x in line.split(',')[1:]]
    float_data[i, :] = values


from matplotlib import pyplot as plt

temp = float_data[:, 1]  # temperature (in degrees Celsius)
plt.plot(range(len(temp)), temp)
plt.show()
```




```
plt.plot(range(1440), temp[:1440])
plt.show()
```



Preparing Data

```
mean = float_data[:200000].mean(axis=0)
float_data -= mean
std = float_data[:200000].std(axis=0)
float_data /= std
```

```
def generator(data, lookback, delay, min_index, max_index,
              shuffle=False, batch_size=128, step=6):
    if max_index is None:
        max_index = len(data) - delay - 1
    i = min_index + lookback
    while 1:
        if shuffle:
            rows = np.random.randint(
                min_index + lookback, max_index, size=batch_size)
        else:
            if i + batch_size >= max_index:
                i = min_index + lookback
            rows = np.arange(i, min(i + batch_size, max_index))
            i += len(rows)
```

```
            i += len(rows)

        samples = np.zeros((len(rows),
                            lookback // step,
                            data.shape[-1]))
        targets = np.zeros((len(rows),))
        for j, row in enumerate(rows):
            indices = range(rows[j] - lookback, rows[j], step)
            samples[j] = data[indices]
            targets[j] = data[rows[j] + delay][1]
        yield samples, targets


lookback = 1440
step = 6
delay = 144
batch_size = 128

train_gen = generator(float_data,
                      lookback=lookback,
                      delay=delay,
                      min_index=0,
                      max_index=200000,
                      shuffle=True,
                      step=step,
                      batch_size=batch_size)
val_gen = generator(float_data,
                    lookback=lookback,
                    delay=delay,
                    min_index=200001,
                    max_index=300000,
                    step=step,
                    batch_size=batch_size)
test_gen = generator(float_data,
                     lookback=lookback,
                     delay=delay,
                     min_index=300001,
                     max_index=None,
                     step=step,
                     batch_size=batch_size)

# This is how many steps to draw from `val_gen`
# in order to see the whole validation set:
val_steps = (300000 - 200001 - lookback) // batch_size

# This is how many steps to draw from `test_gen`
# in order to see the whole test set:
test_steps = (len(float_data) - 300001 - lookback) // batch_size
```

Machine Learning Baseline

```
np.mean(np.abs(preds - targets))
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
<ipython-input-11-2c3bc3683db5> in <module>()
----> 1 np.mean(np.abs(preds - targets))

NameError: name 'preds' is not defined
```

SEARCH STACK OVERFLOW

```
def evaluate_naive_method():
    batch_maes = []
    for step in range(val_steps):
        samples, targets = next(val_gen)
        preds = samples[:, -1, 1]
        mae = np.mean(np.abs(preds - targets))
        batch_maes.append(mae)
    print(np.mean(batch_maes))

evaluate_naive_method()
```

```
0.2897359729905486
```

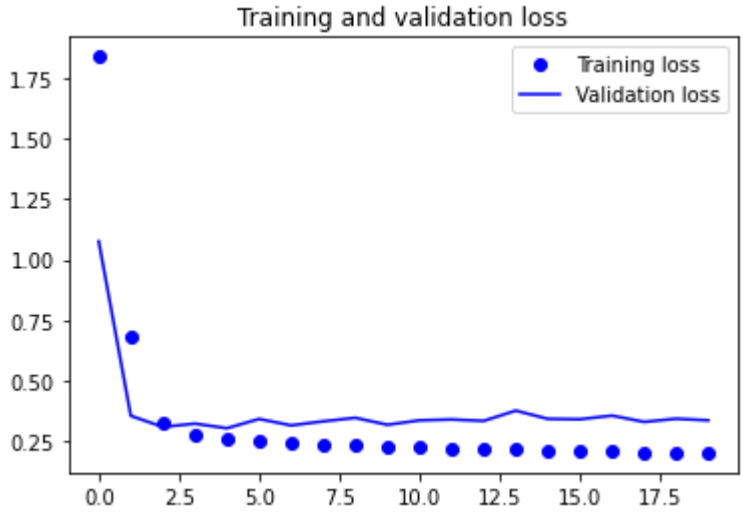
Basic ML Approach

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.Flatten(input_shape=(lookback // step, float_data.shape[-1])))
model.add(layers.Dense(32, activation='relu'))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 17s 32ms/step - loss: 2.4982 - val_loss: 1.07
Epoch 2/20
500/500 [==============================] - 16s 32ms/step - loss: 0.8646 - val_loss: 0.35
```

```
Epoch 3/20
500/500 [==============================] - 16s 32ms/step - loss: 0.3507 - val_loss: 0.30
Epoch 4/20
500/500 [==============================] - 16s 31ms/step - loss: 0.2802 - val_loss: 0.32
Epoch 5/20
500/500 [==============================] - 16s 31ms/step - loss: 0.2613 - val_loss: 0.30
Epoch 6/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2467 - val_loss: 0.33
Epoch 7/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2423 - val_loss: 0.31
Epoch 8/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2341 - val_loss: 0.32
Epoch 9/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2308 - val_loss: 0.34
Epoch 10/20
500/500 [==============================] - 16s 31ms/step - loss: 0.2249 - val_loss: 0.31
Epoch 11/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2208 - val_loss: 0.33
Epoch 12/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2177 - val_loss: 0.33
Epoch 13/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2140 - val_loss: 0.33
Epoch 14/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2113 - val_loss: 0.37
Epoch 15/20
500/500 [==============================] - 16s 32ms/step - loss: 0.2078 - val_loss: 0.33
Epoch 16/20
500/500 [==============================] - 16s 31ms/step - loss: 0.2067 - val_loss: 0.33
Epoch 17/20
500/500 [==============================] - 15s 31ms/step - loss: 0.2026 - val_loss: 0.35
Epoch 18/20
500/500 [==============================] - 16s 31ms/step - loss: 0.2027 - val_loss: 0.32
Epoch 19/20
500/500 [==============================] - 16s 31ms/step - loss: 0.2002 - val_loss: 0.34
Epoch 20/20
500/500 [==============================] - 16s 31ms/step - loss: 0.1992 - val_loss: 0.33
```

```
import matplotlib.pyplot as plt

loss = history.history['loss']
val_loss = history.history['val_loss']

epochs = range(len(loss))

plt.figure()

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()

plt.show()
```



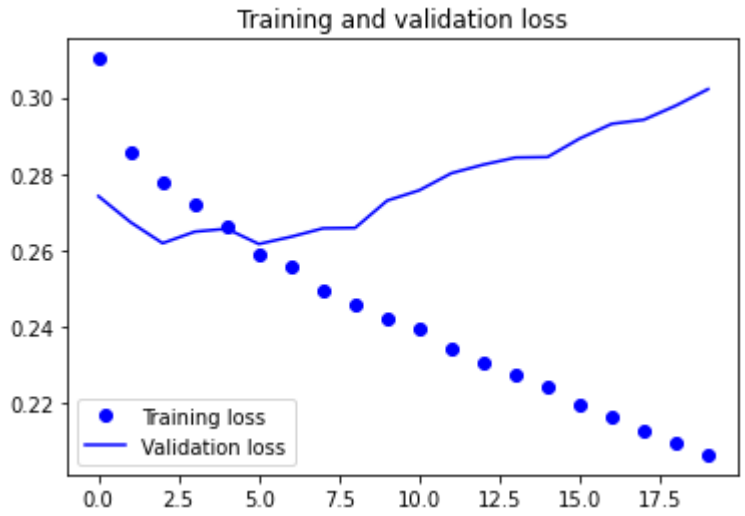
Basic Recurrent Layer

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.GRU(32, input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 86s 168ms/step - loss: 0.3486 - val_loss: 0.2
Epoch 2/20
500/500 [==============================] - 86s 172ms/step - loss: 0.2898 - val_loss: 0.2
Epoch 3/20
500/500 [==============================] - 84s 169ms/step - loss: 0.2797 - val_loss: 0.2
Epoch 4/20
500/500 [==============================] - 86s 172ms/step - loss: 0.2728 - val_loss: 0.2
Epoch 5/20
500/500 [==============================] - 84s 169ms/step - loss: 0.2673 - val_loss: 0.2
Epoch 6/20
500/500 [==============================] - 85s 170ms/step - loss: 0.2601 - val_loss: 0.2
Epoch 7/20
500/500 [==============================] - 85s 170ms/step - loss: 0.2565 - val_loss: 0.2
Epoch 8/20
500/500 [==============================] - 85s 170ms/step - loss: 0.2499 - val_loss: 0.2
Epoch 9/20
500/500 [==============================] - 85s 170ms/step - loss: 0.2465 - val_loss: 0.2
```

```
Epoch 10/20
500/500 [==============================] - 85s 170ms/step - loss: 0.2424 - val_loss: 0.2
Epoch 11/20
500/500 [==============================] - 85s 171ms/step - loss: 0.2411 - val_loss: 0.2
Epoch 12/20
500/500 [==============================] - 85s 171ms/step - loss: 0.2373 - val_loss: 0.2
Epoch 13/20
500/500 [==============================] - 84s 169ms/step - loss: 0.2324 - val_loss: 0.2
Epoch 14/20
500/500 [==============================] - 85s 171ms/step - loss: 0.2306 - val_loss: 0.2
Epoch 15/20
500/500 [==============================] - 84s 168ms/step - loss: 0.2256 - val_loss: 0.2
Epoch 16/20
500/500 [==============================] - 86s 172ms/step - loss: 0.2213 - val_loss: 0.2
Epoch 17/20
500/500 [==============================] - 84s 169ms/step - loss: 0.2171 - val_loss: 0.2
Epoch 18/20
500/500 [==============================] - 86s 173ms/step - loss: 0.2127 - val_loss: 0.2
Epoch 19/20
500/500 [==============================] - 84s 169ms/step - loss: 0.2097 - val_loss: 0.2
Epoch 20/20
500/500 [==============================] - 84s 168ms/step - loss: 0.2063 - val_loss: 0.3
```

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

epochs = range(len(loss))

plt.figure()

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()

plt.show()
```



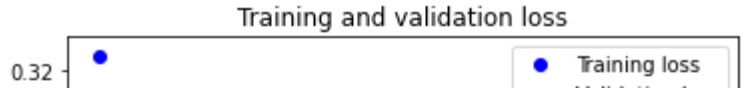
Recurrent with Dropout

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.GRU(32,
                     dropout=0.2,
                     recurrent_dropout=0.2,
                     input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=40,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
Epoch 12/40
500/500 [==============================] - 139s 278ms/step - loss: 0.2652 - val_loss:
Epoch 13/40
500/500 [==============================] - 139s 278ms/step - loss: 0.2677 - val_loss:
Epoch 14/40
500/500 [==============================] - 143s 286ms/step - loss: 0.2634 - val_loss:
Epoch 15/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2607 - val_loss:
Epoch 16/40
500/500 [==============================] - 139s 278ms/step - loss: 0.2582 - val_loss:
Epoch 17/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2563 - val_loss:
Epoch 18/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2533 - val_loss:
Epoch 19/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2530 - val_loss:
Epoch 20/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2504 - val_loss:
Epoch 21/40
500/500 [==============================] - 140s 279ms/step - loss: 0.2510 - val_loss:
Epoch 22/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2467 - val_loss:
Epoch 23/40
500/500 [==============================] - 141s 281ms/step - loss: 0.2442 - val_loss:
Epoch 24/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2425 - val_loss:
Epoch 25/40
500/500 [==============================] - 141s 282ms/step - loss: 0.2423 - val_loss:
Epoch 26/40
500/500 [==============================] - 143s 286ms/step - loss: 0.2416 - val_loss:
Epoch 27/40
500/500 [==============================] - 141s 282ms/step - loss: 0.2405 - val_loss:
Epoch 28/40
```

```
Epoch 28/40
500/500 [==============================] - 141s 282ms/step - loss: 0.2373 - val_loss:
Epoch 29/40
500/500 [==============================] - 141s 283ms/step - loss: 0.2360 - val_loss:
Epoch 30/40
500/500 [==============================] - 141s 283ms/step - loss: 0.2361 - val_loss:
Epoch 31/40
500/500 [==============================] - 141s 282ms/step - loss: 0.2358 - val_loss:
Epoch 32/40
500/500 [==============================] - 141s 282ms/step - loss: 0.2344 - val_loss:
Epoch 33/40
500/500 [==============================] - 142s 284ms/step - loss: 0.2333 - val_loss:
Epoch 34/40
500/500 [==============================] - 142s 283ms/step - loss: 0.2343 - val_loss:
Epoch 35/40
500/500 [==============================] - 140s 281ms/step - loss: 0.2318 - val_loss:
Epoch 36/40
500/500 [==============================] - 140s 281ms/step - loss: 0.2306 - val_loss:
Epoch 37/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2292 - val_loss:
Epoch 38/40
500/500 [==============================] - 140s 280ms/step - loss: 0.2278 - val_loss:
Epoch 39/40
500/500 [==============================] - 140s 279ms/step - loss: 0.2295 - val_loss:
Epoch 40/40
500/500 [==============================] - 139s 279ms/step - loss: 0.2267 - val_loss:
```

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

epochs = range(len(loss))

plt.figure()

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()

plt.show()
```



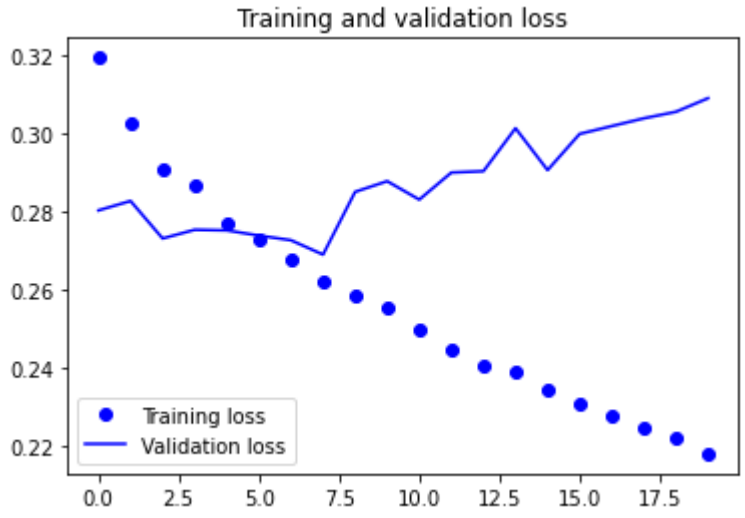
Stacking Recurrent Layers

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.GRU(32,
                     dropout=0.1,
                     recurrent_dropout=0.5,
                     return_sequences=True,
                     input_shape=(None, float_data.shape[-1])))
model.add(layers.GRU(64, activation='relu',
                     dropout=0.1,
                     recurrent_dropout=0.5))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 393s 776ms/step - loss: 0.3426 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 387s 774ms/step - loss: 0.3045 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 388s 776ms/step - loss: 0.2955 - val_loss: 0
Epoch 4/20
500/500 [==============================] - 390s 780ms/step - loss: 0.2886 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 388s 776ms/step - loss: 0.2778 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 389s 779ms/step - loss: 0.2743 - val_loss: 0
Epoch 7/20
500/500 [==============================] - 390s 781ms/step - loss: 0.2686 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 394s 789ms/step - loss: 0.2633 - val_loss: 0
Epoch 9/20
500/500 [==============================] - 400s 801ms/step - loss: 0.2599 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 394s 788ms/step - loss: 0.2561 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 393s 786ms/step - loss: 0.2503 - val_loss: 0
```

```
Epoch 12/20
500/500 [==============================] - 394s 788ms/step - loss: 0.2446 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 391s 782ms/step - loss: 0.2403 - val_loss: 0
Epoch 14/20
500/500 [==============================] - 391s 781ms/step - loss: 0.2408 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 390s 780ms/step - loss: 0.2360 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 389s 778ms/step - loss: 0.2323 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 390s 780ms/step - loss: 0.2283 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 390s 780ms/step - loss: 0.2248 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 391s 782ms/step - loss: 0.2225 - val_loss: 0
Epoch 20/20
500/500 [==============================] - 394s 789ms/step - loss: 0.2197 - val_loss: 0
```

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

epochs = range(len(loss))

plt.figure()

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()

plt.show()
```



Bidirectional RNN

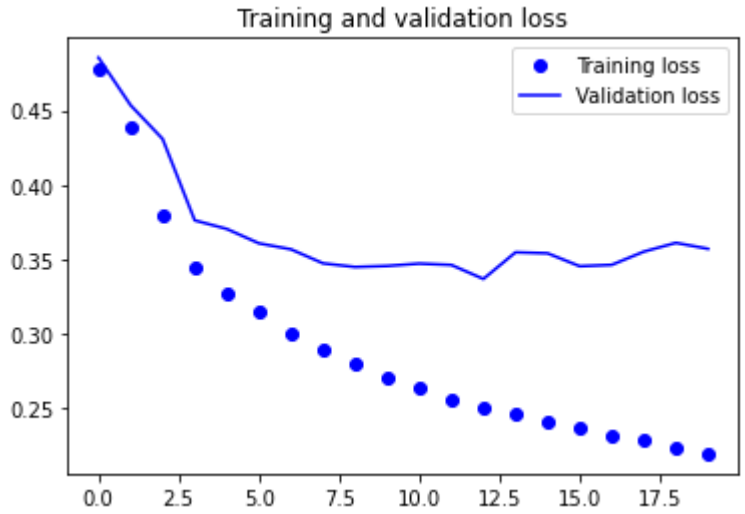
```
def reverse_order_generator(data, lookback, delay, min_index, max_index,
                            shuffle=False, batch_size=128, step=6):
    if max_index is None:
        max_index = len(data) - delay - 1
    i = min_index + lookback
    while 1:
        if shuffle:
            rows = np.random.randint(
                min_index + lookback, max_index, size=batch_size)
        else:
            if i + batch_size >= max_index:
                i = min_index + lookback
            rows = np.arange(i, min(i + batch_size, max_index))
            i += len(rows)

        samples = np.zeros((len(rows),
                            lookback // step,
                            data.shape[-1]))
        targets = np.zeros((len(rows),))
        for j, row in enumerate(rows):
            indices = range(rows[j] - lookback, rows[j], step)
            samples[j] = data[indices]
            targets[j] = data[rows[j] + delay][1]
        yield samples[:, ::-1, :], targets

train_gen_reverse = reverse_order_generator(
    float_data,
    lookback=lookback,
    delay=delay,
    min_index=0,
    max_index=200000,
    shuffle=True,
    step=step,
    batch_size=batch_size)
val_gen_reverse = reverse_order_generator(
    float_data,
    lookback=lookback,
    delay=delay,
    min_index=200001,
    max_index=300000,
    step=step,
    batch_size=batch_size)


model = Sequential()
model.add(layers.GRU(32, input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen_reverse,
                              steps_per_epoch=500,
```

```
                              epochs=20,
                              validation_data=val_gen_reverse,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 88s 173ms/step - loss: 0.4950 - val_loss: 0.4
Epoch 2/20
500/500 [==============================] - 84s 168ms/step - loss: 0.4526 - val_loss: 0.4
Epoch 3/20
500/500 [==============================] - 84s 169ms/step - loss: 0.3899 - val_loss: 0.4
Epoch 4/20
500/500 [==============================] - 85s 171ms/step - loss: 0.3515 - val_loss: 0.3
Epoch 5/20
500/500 [==============================] - 85s 169ms/step - loss: 0.3292 - val_loss: 0.3
Epoch 6/20
500/500 [==============================] - 85s 169ms/step - loss: 0.3174 - val_loss: 0.3
Epoch 7/20
500/500 [==============================] - 86s 171ms/step - loss: 0.3027 - val_loss: 0.3
Epoch 8/20
500/500 [==============================] - 84s 168ms/step - loss: 0.2918 - val_loss: 0.3
Epoch 9/20
500/500 [==============================] - 88s 177ms/step - loss: 0.2819 - val_loss: 0.3
Epoch 10/20
500/500 [==============================] - 86s 172ms/step - loss: 0.2718 - val_loss: 0.3
Epoch 11/20
500/500 [==============================] - 87s 173ms/step - loss: 0.2671 - val_loss: 0.3
Epoch 12/20
500/500 [==============================] - 85s 169ms/step - loss: 0.2570 - val_loss: 0.3
Epoch 13/20
500/500 [==============================] - 86s 173ms/step - loss: 0.2516 - val_loss: 0.3
Epoch 14/20
500/500 [==============================] - 84s 169ms/step - loss: 0.2468 - val_loss: 0.3
Epoch 15/20
500/500 [==============================] - 85s 170ms/step - loss: 0.2417 - val_loss: 0.3
Epoch 16/20
500/500 [==============================] - 87s 173ms/step - loss: 0.2398 - val_loss: 0.3
Epoch 17/20
500/500 [==============================] - 86s 172ms/step - loss: 0.2324 - val_loss: 0.3
Epoch 18/20
500/500 [==============================] - 85s 171ms/step - loss: 0.2299 - val_loss: 0.3
Epoch 19/20
500/500 [==============================] - 85s 171ms/step - loss: 0.2256 - val_loss: 0.3
Epoch 20/20
500/500 [==============================] - 86s 172ms/step - loss: 0.2222 - val_loss: 0.3
```

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

epochs = range(len(loss))

plt.figure()

plt.plot(epochs, loss, 'bo', label='Training loss')
```

```
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Training and validation loss')
plt.legend()

plt.show()
```




```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.Bidirectional(
    layers.GRU(32), input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 148s 289ms/step - loss: 0.3234 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 145s 289ms/step - loss: 0.2773 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 143s 287ms/step - loss: 0.2695 - val_loss: 0
Epoch 4/20
500/500 [==============================] - 143s 286ms/step - loss: 0.2653 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 144s 289ms/step - loss: 0.2598 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 146s 292ms/step - loss: 0.2541 - val_loss: 0
Epoch 7/20
```

```
500/500 [==============================] - 144s 288ms/step - loss: 0.2460 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 144s 287ms/step - loss: 0.2416 - val_loss: 0
Epoch 9/20
500/500 [==============================] - 144s 288ms/step - loss: 0.2331 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 144s 288ms/step - loss: 0.2288 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 144s 288ms/step - loss: 0.2225 - val_loss: 0
Epoch 12/20
500/500 [==============================] - 145s 291ms/step - loss: 0.2168 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 144s 287ms/step - loss: 0.2090 - val_loss: 0
Epoch 14/20
500/500 [==============================] - 143s 287ms/step - loss: 0.2039 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 144s 288ms/step - loss: 0.1967 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 145s 289ms/step - loss: 0.1916 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 143s 287ms/step - loss: 0.1895 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 145s 291ms/step - loss: 0.1830 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 143s 287ms/step - loss: 0.1808 - val_loss: 0
Epoch 20/20
500/500 [==============================] - 145s 290ms/step - loss: 0.1768 - val_loss: 0
```

Adjusting Units in Recurrent Layers

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.GRU(16,
                     dropout=0.1,
                     recurrent_dropout=0.5,
                     return_sequences=True,
                     input_shape=(None, float_data.shape[-1])))
model.add(layers.GRU(32, activation='relu',
                     dropout=0.1,
                     recurrent_dropout=0.5))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 270s 530ms/step - loss: 0.3509 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 269s 538ms/step - loss: 0.3088 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 270s 541ms/step - loss: 0.3043 - val_loss: 0
Epoch 4/20
500/500 [==============================] - 267s 533ms/step - loss: 0.2981 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 267s 534ms/step - loss: 0.2941 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 262s 524ms/step - loss: 0.2917 - val_loss: 0
Epoch 7/20
500/500 [==============================] - 262s 524ms/step - loss: 0.2884 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 263s 527ms/step - loss: 0.2827 - val_loss: 0
Epoch 9/20
500/500 [==============================] - 263s 526ms/step - loss: 0.2801 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 264s 528ms/step - loss: 0.2799 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 264s 528ms/step - loss: 0.2765 - val_loss: 0
Epoch 12/20
500/500 [==============================] - 266s 532ms/step - loss: 0.2755 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 265s 531ms/step - loss: 0.2757 - val_loss: 0
Epoch 14/20
500/500 [==============================] - 273s 547ms/step - loss: 0.2697 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 276s 553ms/step - loss: 0.2703 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 266s 532ms/step - loss: 0.2682 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 265s 529ms/step - loss: 0.2674 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 267s 534ms/step - loss: 0.2651 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 267s 534ms/step - loss: 0.2652 - val_loss: 0
Epoch 20/20
500/500 [==============================] - 265s 531ms/step - loss: 0.2641 - val_loss: 0
```

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.GRU(64,
                     dropout=0.1,
                     recurrent_dropout=0.5,
                     return_sequences=True,
                     input_shape=(None, float_data.shape[-1])))
model.add(layers.GRU(128, activation='relu',
```

```
model.add(layers.GRU(128, activation='relu',
                     dropout=0.1,
                     recurrent_dropout=0.5))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=10,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/10
500/500 [==============================] - 857s 2s/step - loss: 0.3287 - val_loss: 0.284
Epoch 2/10
500/500 [==============================] - 854s 2s/step - loss: 0.2998 - val_loss: 0.276
Epoch 3/10
500/500 [==============================] - 847s 2s/step - loss: 0.2854 - val_loss: 0.275
Epoch 4/10
500/500 [==============================] - 850s 2s/step - loss: 0.2764 - val_loss: 0.268
Epoch 5/10
500/500 [==============================] - 852s 2s/step - loss: 0.2629 - val_loss: 0.275
Epoch 6/10
500/500 [==============================] - 854s 2s/step - loss: 0.2538 - val_loss: 0.285
Epoch 7/10
500/500 [==============================] - 851s 2s/step - loss: 0.2407 - val_loss: 0.287
Epoch 8/10
500/500 [==============================] - 846s 2s/step - loss: 0.2330 - val_loss: 0.286
Epoch 9/10
500/500 [==============================] - 849s 2s/step - loss: 0.2233 - val_loss: 0.298
Epoch 10/10
500/500 [==============================] - 846s 2s/step - loss: 0.2157 - val_loss: 0.306
```

Swapping LSTM for GRU

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.LSTM(32,
                      dropout=0.1,
                      recurrent_dropout=0.5,
                      return_sequences=True,
                      input_shape=(None, float_data.shape[-1])))
model.add(layers.LSTM(64, activation='relu',
                      dropout=0.1,
                      recurrent_dropout=0.5))
model.add(layers.Dense(1))
```

```
model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 460s 910ms/step - loss: 0.3654 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 455s 909ms/step - loss: nan - val_loss: nan
Epoch 3/20
500/500 [==============================] - 459s 918ms/step - loss: nan - val_loss: nan
Epoch 4/20
500/500 [==============================] - 458s 916ms/step - loss: nan - val_loss: nan
Epoch 5/20
500/500 [==============================] - 458s 917ms/step - loss: nan - val_loss: nan
Epoch 6/20
500/500 [==============================] - 459s 919ms/step - loss: nan - val_loss: nan
Epoch 7/20
500/500 [==============================] - 459s 919ms/step - loss: nan - val_loss: nan
Epoch 8/20
500/500 [==============================] - 458s 917ms/step - loss: nan - val_loss: nan
Epoch 9/20
500/500 [==============================] - 457s 915ms/step - loss: nan - val_loss: nan
Epoch 10/20
500/500 [==============================] - 458s 916ms/step - loss: nan - val_loss: nan
Epoch 11/20
500/500 [==============================] - 457s 914ms/step - loss: nan - val_loss: nan
Epoch 12/20
500/500 [==============================] - 459s 918ms/step - loss: nan - val_loss: nan
Epoch 13/20
500/500 [==============================] - 458s 917ms/step - loss: nan - val_loss: nan
Epoch 14/20
500/500 [==============================] - 458s 917ms/step - loss: nan - val_loss: nan
Epoch 15/20
500/500 [==============================] - 458s 917ms/step - loss: nan - val_loss: nan
Epoch 16/20
500/500 [==============================] - 459s 918ms/step - loss: nan - val_loss: nan
Epoch 17/20
500/500 [==============================] - 458s 916ms/step - loss: nan - val_loss: nan
Epoch 18/20
500/500 [==============================] - 457s 915ms/step - loss: nan - val_loss: nan
Epoch 19/20
500/500 [==============================] - 457s 914ms/step - loss: nan - val_loss: nan
Epoch 20/20
500/500 [==============================] - 457s 914ms/step - loss: nan - val_loss: nan
```

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop
```

```
model = Sequential()
model.add(layers.LSTM(32,
                      dropout=0.2,
                      recurrent_dropout=0.2,
                      input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(train_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=val_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 165s 325ms/step - loss: 0.3604 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 162s 325ms/step - loss: 0.2926 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2840 - val_loss: 0
Epoch 4/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2776 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 163s 327ms/step - loss: 0.2715 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2656 - val_loss: 0
Epoch 7/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2641 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2575 - val_loss: 0
Epoch 9/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2522 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2501 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 163s 327ms/step - loss: 0.2473 - val_loss: 0
Epoch 12/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2427 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2404 - val_loss: 0
Epoch 14/20
500/500 [==============================] - 163s 327ms/step - loss: 0.2361 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 164s 327ms/step - loss: 0.2333 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 164s 328ms/step - loss: 0.2303 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 163s 326ms/step - loss: 0.2316 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 163s 327ms/step - loss: 0.2280 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 164s 328ms/step - loss: 0.2256 - val_loss: 0
```

```
Epoch 20/20
500/500 [==============================] - 164s 328ms/step - loss: 0.2241 - val_loss: 0
```

Testing Top 3 Models

Basic Recurrent Layer

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.GRU(32, input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(test_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=test_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 108s 212ms/step - loss: 0.3292 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 105s 210ms/step - loss: 0.2903 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 107s 214ms/step - loss: 0.2832 - val_loss: 0
Epoch 4/20
500/500 [==============================] - 105s 210ms/step - loss: 0.2688 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 108s 216ms/step - loss: 0.2927 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 104s 209ms/step - loss: 0.2612 - val_loss: 0
Epoch 7/20
500/500 [==============================] - 105s 210ms/step - loss: 0.3143 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 105s 211ms/step - loss: 0.2642 - val_loss: 0
Epoch 9/20
500/500 [==============================] - 107s 214ms/step - loss: 0.2963 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 108s 217ms/step - loss: 0.2555 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 109s 217ms/step - loss: 0.2794 - val_loss: 0
Epoch 12/20
500/500 [==============================] - 108s 217ms/step - loss: 0.2727 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 106s 212ms/step - loss: 0.2708 - val_loss: 0
```

```
Epoch 14/20
500/500 [==============================] - 108s 216ms/step - loss: 0.2843 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 105s 211ms/step - loss: 0.2701 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 107s 215ms/step - loss: 0.2728 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 106s 212ms/step - loss: 0.2481 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 106s 212ms/step - loss: 0.2741 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 106s 213ms/step - loss: 0.2447 - val_loss: 0
Epoch 20/20
500/500 [==============================] - 107s 215ms/step - loss: 0.2946 - val_loss: 0
```

Bidirectional RNN

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.Bidirectional(
    layers.GRU(32), input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(test_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=test_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 188s 367ms/step - loss: 0.3108 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 181s 362ms/step - loss: 0.3352 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 181s 363ms/step - loss: 0.2715 - val_loss: 0
Epoch 4/20
500/500 [==============================] - 182s 365ms/step - loss: 0.2943 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 185s 370ms/step - loss: 0.2803 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 183s 367ms/step - loss: 0.2726 - val_loss: 0
Epoch 7/20
500/500 [==============================] - 182s 364ms/step - loss: 0.2816 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 182s 363ms/step - loss: 0.2703 - val_loss: 0
Epoch 9/20
```

```
500/500 [==============================] - 180s 361ms/step - loss: 0.2809 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 182s 363ms/step - loss: 0.2485 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 183s 367ms/step - loss: 0.2764 - val_loss: 0
Epoch 12/20
500/500 [==============================] - 180s 360ms/step - loss: 0.2446 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 180s 360ms/step - loss: 0.2988 - val_loss: 0
Epoch 14/20
500/500 [==============================] - 181s 362ms/step - loss: 0.2487 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 183s 366ms/step - loss: 0.3018 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 186s 373ms/step - loss: 0.2482 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 188s 375ms/step - loss: 0.2604 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 183s 367ms/step - loss: 0.2571 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 181s 362ms/step - loss: 0.2499 - val_loss: 0
Epoch 20/20
500/500 [==============================] - 182s 364ms/step - loss: 0.2680 - val_loss: 0
```

Swapping LSTM for GRU

```
from keras.models import Sequential
from keras import layers
from keras.optimizers import RMSprop

model = Sequential()
model.add(layers.LSTM(32,
                      dropout=0.2,
                      recurrent_dropout=0.2,
                      input_shape=(None, float_data.shape[-1])))
model.add(layers.Dense(1))

model.compile(optimizer=RMSprop(), loss='mae')
history = model.fit_generator(test_gen,
                              steps_per_epoch=500,
                              epochs=20,
                              validation_data=val_gen,
                              validation_steps=test_steps)
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/keras/engine/training.py:1844:
  warnings.warn('`Model.fit_generator` is deprecated and '
Epoch 1/20
500/500 [==============================] - 192s 379ms/step - loss: 0.3399 - val_loss: 0
Epoch 2/20
500/500 [==============================] - 190s 379ms/step - loss: 0.3051 - val_loss: 0
Epoch 3/20
500/500 [==============================] - 190s 380ms/step - loss: 0.2769 - val_loss: 0
```

```
Epoch 4/20
500/500 [==============================] - 190s 380ms/step - loss: 0.2938 - val_loss: 0
Epoch 5/20
500/500 [==============================] - 191s 382ms/step - loss: 0.2682 - val_loss: 0
Epoch 6/20
500/500 [==============================] - 190s 381ms/step - loss: 0.3188 - val_loss: 0
Epoch 7/20
500/500 [==============================] - 190s 380ms/step - loss: 0.2678 - val_loss: 0
Epoch 8/20
500/500 [==============================] - 191s 382ms/step - loss: 0.3159 - val_loss: 0
Epoch 9/20
500/500 [==============================] - 191s 382ms/step - loss: 0.2617 - val_loss: 0
Epoch 10/20
500/500 [==============================] - 193s 385ms/step - loss: 0.2804 - val_loss: 0
Epoch 11/20
500/500 [==============================] - 190s 381ms/step - loss: 0.2744 - val_loss: 0
Epoch 12/20
500/500 [==============================] - 190s 380ms/step - loss: 0.2705 - val_loss: 0
Epoch 13/20
500/500 [==============================] - 194s 388ms/step - loss: 0.2791 - val_loss: 0
Epoch 14/20
500/500 [==============================] - 192s 384ms/step - loss: 0.2715 - val_loss: 0
Epoch 15/20
500/500 [==============================] - 193s 385ms/step - loss: 0.2720 - val_loss: 0
Epoch 16/20
500/500 [==============================] - 193s 387ms/step - loss: 0.2524 - val_loss: 0
Epoch 17/20
500/500 [==============================] - 194s 389ms/step - loss: 0.2693 - val_loss: 0
Epoch 18/20
500/500 [==============================] - 193s 387ms/step - loss: 0.2485 - val_loss: 0
Epoch 19/20
500/500 [==============================] - 194s 388ms/step - loss: 0.3025 - val_loss: 0
Epoch 20/20
500/500 [==============================] - 191s 382ms/step - loss: 0.2506 - val_loss: 0
```

✓ 1h 3m 51s completed at 5:54 PM