Q2_Linear_Autoencoder

March 24, 2022

1 Allowing Import from Parent Directory

[2]:
```
import os
import sys
import inspect

currentdir = os.path.dirname(os.path.abspath(inspect.getfile(inspect.
 ↪currentframe())))
parentdir = os.path.dirname(currentdir)
sys.path.insert(0, parentdir)
```

2 Importing Packages

[1]:
```
import glob
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import time
import tools.loaddata as loaddata
import tools.dataassimilation as da
import tools.visualisation as visual

import sklearn
assert sklearn.__version__ >= "0.20"
from sklearn.metrics import mean_squared_error
from sklearn.decomposition import PCA

# TensorFlow 2.0 is required
import tensorflow as tf
from tensorflow import keras
assert tf.__version__ >= "2.0"
```

3 Loading and reshaping data

[ ]:
```
path_train = "../data/train/"
path_test = "../data/test/"
path_back = "../data/background/"
path_obs = "../data/satellite/"
```

[3]:
```
train_full, test, model_data, satellite_data = loaddata.
 ↪load_all_data(path_train, path_test, path_back, path_obs)
```

[4]:
```
train = train_full[0:1200]
```

[5]:
```
print(f"Train data before reshaping: {np.shape(train)}")
print(f"Test data before reshaping: {np.shape(test)}")
print(f"background data before reshaping: {np.shape(model_data)}")
print(f"observational data before reshaping: {np.shape(satellite_data)}")
```

```
Train data before reshaping: (1200, 871, 913)
Test data before reshaping: (300, 871, 913)
background data before reshaping: (5, 871, 913)
observational data before reshaping: (5, 871, 913)
```

[6]:
```
train_1D, test_1D, model_data_1D, satellite_data_1D = loaddata.
 ↪reshape_all_datasets(train, test, model_data, satellite_data)
```

[7]:
```
print(f"Train data after reshaping: {train_1D.shape}")
print(f"Test data after reshaping: {test_1D.shape}")
print(f"Model data after reshaping: {model_data_1D.shape}")
print(f"Observational data after reshaping: {satellite_data_1D.shape}")
```

```
Train data after reshaping: (1200, 795223)
Test data after reshaping: (300, 795223)
Model data after reshaping: (5, 795223)
Observational data after reshaping: (5, 795223)
```

4 Linear Autoencoder

[8]:
```
early_stopping = keras.callbacks.EarlyStopping(monitor='val_loss',
                                               min_delta=0.0,
                                               patience=50,
                                               verbose=2,
                                               restore_best_weights=True)
```

[9]:
```
encoder = keras.models.Sequential([keras.layers.Dense(15, input_shape=[795223],␣
 ↪activation="linear")])
```

```
decoder = keras.models.Sequential([keras.layers.Dense(795223, input_shape=[15],␣
 ↪activation="linear")])
autoencoder = keras.models.Sequential([encoder, decoder])

autoencoder.compile(loss="mse",
                    optimizer=keras.optimizers.Adam(learning_rate=0.001,␣
 ↪beta_1=0.9, beta_2=0.999)
                    )
autoencoder.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 sequential (Sequential)     (None, 15)                11928360

 sequential_1 (Sequential)   (None, 795223)            12723568

=================================================================
Total params: 24,651,928
Trainable params: 24,651,928
Non-trainable params: 0
_________________________________________________________________
```

[10]:
```
history = autoencoder.fit(train_1D,
                          train_1D,
                          epochs=20,
                          validation_data=(train_1D, train_1D),
                          callbacks=[early_stopping])
```

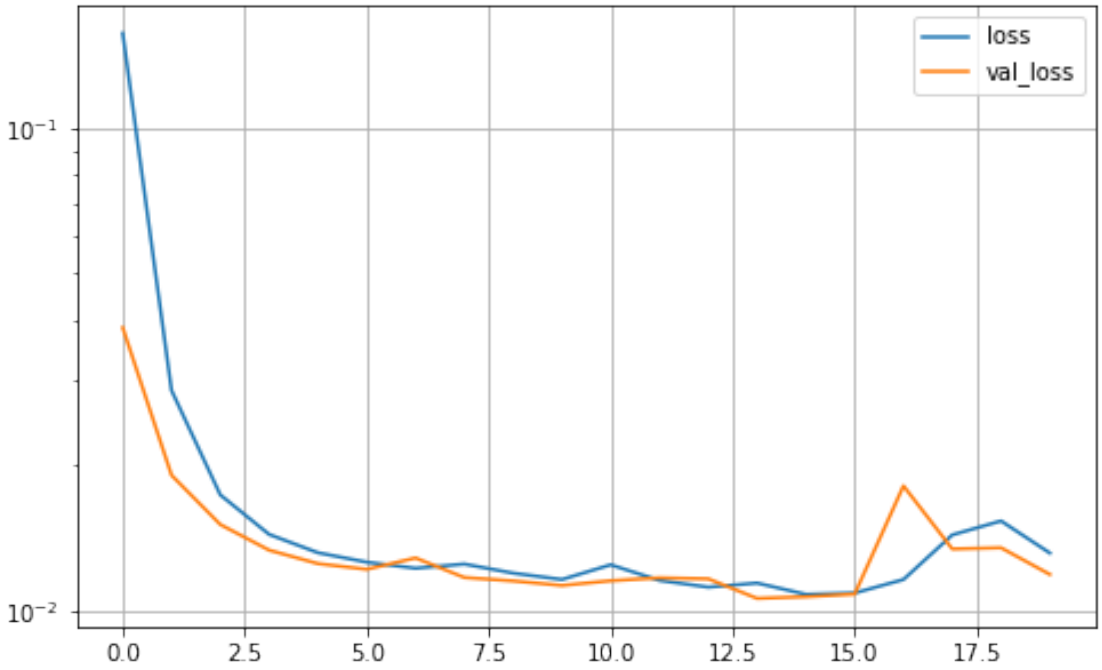
```
Epoch 1/20
38/38 [==============================] - 9s 208ms/step - loss: 0.1573 -
val_loss: 0.0386
Epoch 2/20
38/38 [==============================] - 7s 185ms/step - loss: 0.0286 -
val_loss: 0.0191
Epoch 3/20
38/38 [==============================] - 7s 184ms/step - loss: 0.0174 -
val_loss: 0.0151
Epoch 4/20
38/38 [==============================] - 7s 186ms/step - loss: 0.0144 -
val_loss: 0.0134
Epoch 5/20
38/38 [==============================] - 7s 190ms/step - loss: 0.0132 -
val_loss: 0.0125
Epoch 6/20
38/38 [==============================] - 7s 188ms/step - loss: 0.0126 -
```

```
val_loss: 0.0122
Epoch 7/20
38/38 [==============================] - 7s 188ms/step - loss: 0.0122 -
val_loss: 0.0129
Epoch 8/20
38/38 [==============================] - 7s 188ms/step - loss: 0.0125 -
val_loss: 0.0117
Epoch 9/20
38/38 [==============================] - 7s 187ms/step - loss: 0.0120 -
val_loss: 0.0115
Epoch 10/20
38/38 [==============================] - 7s 189ms/step - loss: 0.0116 -
val_loss: 0.0113
Epoch 11/20
38/38 [==============================] - 7s 184ms/step - loss: 0.0125 -
val_loss: 0.0115
Epoch 12/20
38/38 [==============================] - 7s 178ms/step - loss: 0.0116 -
val_loss: 0.0117
Epoch 13/20
38/38 [==============================] - 7s 177ms/step - loss: 0.0112 -
val_loss: 0.0116
Epoch 14/20
38/38 [==============================] - 7s 174ms/step - loss: 0.0114 -
val_loss: 0.0106
Epoch 15/20
38/38 [==============================] - 7s 174ms/step - loss: 0.0108 -
val_loss: 0.0107
Epoch 16/20
38/38 [==============================] - 6s 171ms/step - loss: 0.0109 -
val_loss: 0.0108
Epoch 17/20
38/38 [==============================] - 6s 171ms/step - loss: 0.0116 -
val_loss: 0.0181
Epoch 18/20
38/38 [==============================] - 6s 171ms/step - loss: 0.0144 -
val_loss: 0.0134
Epoch 19/20
38/38 [==============================] - 6s 171ms/step - loss: 0.0153 -
val_loss: 0.0135
Epoch 20/20
38/38 [==============================] - 6s 169ms/step - loss: 0.0132 -
val_loss: 0.0119
```

[11]:
```
print(history.history.keys())
print('best value: ', autoencoder.evaluate(train_1D, train_1D, verbose=0))
```

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

```
dict_keys(['loss', 'val_loss'])
best value:  0.011890673078596592
```



[12]:
```
test_recovered = autoencoder.predict(test_1D)
mse_test = da.mse(test_1D, test_recovered)
print('mse: ', mse_test)
```

```
mse:  0.011044955676303942
```

5 Data Assimilation - Kalman Filter (BLUE)

[13]:
```
model_data_compr = encoder.predict(model_data_1D)
satellite_data_compr = encoder.predict(satellite_data_1D)

latent_space = satellite_data_compr.shape[1]
nNodes = latent_space  # latent_space is the size of the compressed variables␣
↪or number of principal components used
I = np.identity(nNodes)
R = np.cov(satellite_data_compr.T)
```

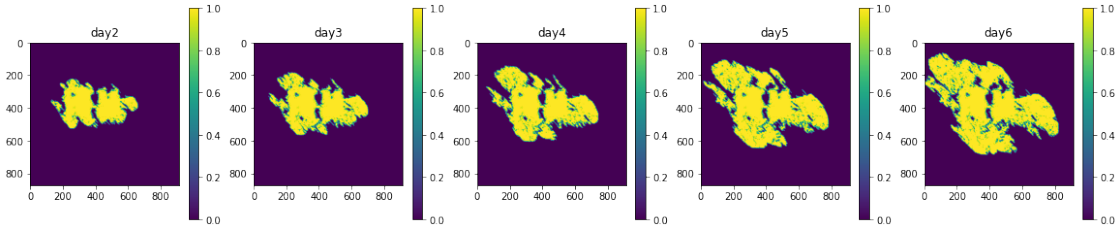
```
H = I
B = 0.001 * I
```

[14]:
```
## Performing data assimilation
updated_data_array = da.assimilate(B, H, R, model_data_compr,␣
 ↪satellite_data_compr)

## Printing MSE in latent space
mse_before_DA = da.mse(satellite_data_compr, model_data_compr)
mse_after_DA = da.mse(satellite_data_compr, updated_data_array)
print('MSE before assimilation in latent space: ', mse_before_DA )
print('MSE after assimilation in latent space: ', mse_after_DA)

## Printing MSE in Physical space space
updated_data_recon = decoder.predict(updated_data_array)
mse_before_DA_physical = da.mse(satellite_data_1D, model_data_1D)
mse_after_DA_physical = da.mse(satellite_data_1D, updated_data_recon)

print('MSE before assimilation in physical space: ', mse_before_DA_physical)
print('MSE after assimilation in physical space: ', mse_after_DA_physical)
```

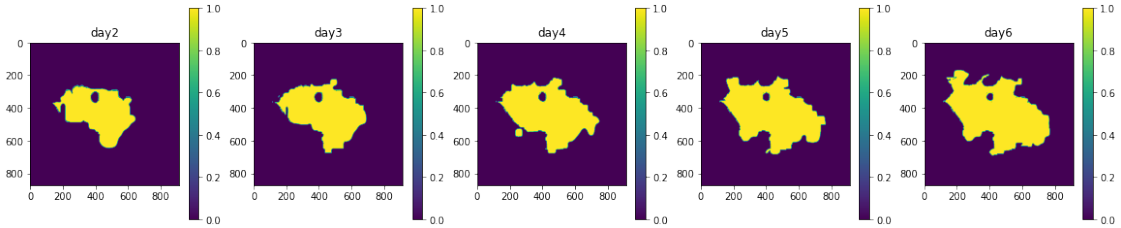
```
MSE before assimilation in latent space:  813.7622
MSE after assimilation in latent space:  325.128050404119
MSE before assimilation in physical space:  0.1191695914227833
MSE after assimilation in physical space:  0.07752281741861795
```

6 Visualising Results

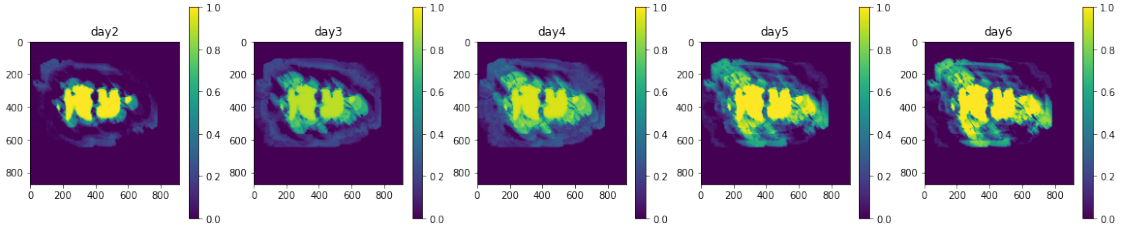
[15]:
```
# Plot model data
visual.plot_data(model_data)
```



[16]:
```
# Plot satellite data
visual.plot_data(satellite_data)
```



[17]:
```
# Plot reconstructed model
updated_data_recon = np.reshape(updated_data_recon, (5, 871, 913))
visual.plot_data(updated_data_recon)
```



[ ]:
```
!wget -nc https://raw.githubusercontent.com/brpy/colab-pdf/master/colab_pdf.py
from colab_pdf import colab_pdf
colab_pdf('Q2_Linear_Autoencoder.ipynb')
```

```
--2022-03-24 19:15:33--  https://raw.githubusercontent.com/brpy/colab-
pdf/master/colab_pdf.py
Resolving raw.githubusercontent.com (raw.githubusercontent.com)…
185.199.108.133, 185.199.109.133, 185.199.110.133, …
Connecting to raw.githubusercontent.com
(raw.githubusercontent.com)|185.199.108.133|:443… connected.
HTTP request sent, awaiting response… 200 OK
Length: 1864 (1.8K) [text/plain]
Saving to: ‘colab_pdf.py’

colab_pdf.py        100%[===================>]   1.82K  --.-KB/s    in 0s

2022-03-24 19:15:33 (36.8 MB/s) - ‘colab_pdf.py’ saved [1864/1864]

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WARNING: apt does not have a stable CLI interface. Use with caution in scripts.


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```

```
Extracting templates from packages: 100%
```