Q2_Nonlinear_Autoencoder

March 23, 2022

1 Allowing Import from Parent Directory

[12]:
```
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

[2]:
```
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/"
```

[4]:
```
train_full, test, model_data, satellite_data = loaddata.
↪load_all_data(path_train, path_test, path_back, path_obs)
```

[5]:
```
train = train_full[0:1200]
```

[6]:
```
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)
```

[7]:
```
train_1D, test_1D, model_data_1D, satellite_data_1D = loaddata.
↪reshape_all_datasets(train, test, model_data, satellite_data)
```

[8]:
```
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 Non-linear Autoencoder

[9]:
```
np.random.seed(42)
tf.random.set_seed(42)

encoder = keras.models.Sequential([keras.layers.Dense(128,␣
↪input_shape=[795223], activation="elu"),
                                   keras.layers.Dense(64)])
decoder = keras.models.Sequential([keras.layers.Dense(128, input_shape=[64],␣
↪activation="elu"),
```

```
                                    keras.layers.Dense(795223,␣
 ↪activation='sigmoid')])
autoencoder = keras.models.Sequential([encoder, decoder])

autoencoder.compile(loss='binary_crossentropy',
                    optimizer=keras.optimizers.Adam(),
                    metrics=['mse'])
print('Encoder:')
encoder.summary()
print('\nDencoder:')
decoder.summary()
print('\nAutoencoder:')
autoencoder.summary()
```

```
Encoder:
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense (Dense)               (None, 128)               101788672

 dense_1 (Dense)             (None, 64)                8256

=================================================================
Total params: 101,796,928
Trainable params: 101,796,928
Non-trainable params: 0
_________________________________________________________________

Dencoder:
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_2 (Dense)             (None, 128)               8320

 dense_3 (Dense)             (None, 795223)            102583767

=================================================================
Total params: 102,592,087
Trainable params: 102,592,087
Non-trainable params: 0
_________________________________________________________________

Autoencoder:
Model: "sequential_2"
_________________________________________________________________
```

```
 Layer (type)                Output Shape              Param #
=================================================================
 sequential (Sequential)     (None, 64)                101796928

 sequential_1 (Sequential)   (None, 795223)            102592087

=================================================================
Total params: 204,389,015
Trainable params: 204,389,015
Non-trainable params: 0
_________________________________________________________________
```

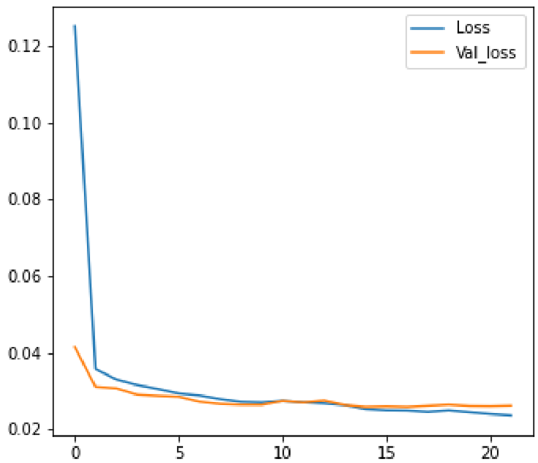
[10]:
```python
# Callback to prevent overfitting

from keras import callbacks
earlystopping = callbacks.EarlyStopping(monitor ="val_loss",
                                        mode ="min", patience = 5,
                                        restore_best_weights = True)
```

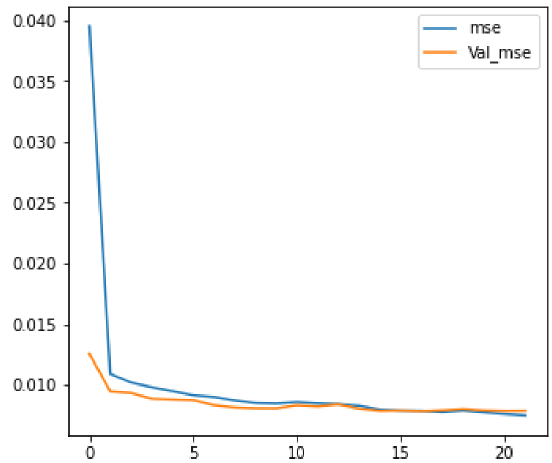
[ ]:
```python
start = time.time()
history = autoencoder.fit(train_1D,
                          train_1D,
                          epochs=50,
                          batch_size=32,
                          verbose=2,
                          validation_data = (test_1D, test_1D),
                          shuffle = True, callbacks = [earlystopping])
time_ae = time.time() - start
print('Execution time: ', time_ae)
```

[13]:
```python
# The validation loss began to increase when the number of epochs
# was at 38. This means that the model begins to overfit the data after 38␣
↪epochs.
# The optimum combination of epoch size and batch size we found is 38 and 32␣
↪respectively, with 64 hidden layers.
```

[14]:
```python
fig, axes = plt.subplots(1,2, figsize=(12,5))
axes[0].plot(history.history['loss'])
axes[0].plot(history.history['val_loss'])
axes[0].legend(['Loss', 'Val_loss'])
axes[1].plot(history.history['mse'])
axes[1].plot(history.history['val_mse'])
axes[1].legend(['mse', 'Val_mse'])
```

[14]: <matplotlib.legend.Legend at 0x7fb6d6da4f10>





[15]:
```
test_recovered = autoencoder.predict(test_1D)
mse_test = da.mse(test_1D, test_recovered)
print('mse: ', mse_test)
```

```
mse:  0.007834356550550689
```

5 Data Assimilation - Kalman Filter (BLUE)

By adjusting the error covariance matrices R and B, we found that the following forms of matrices give us the lowest mse result after data assimilation.

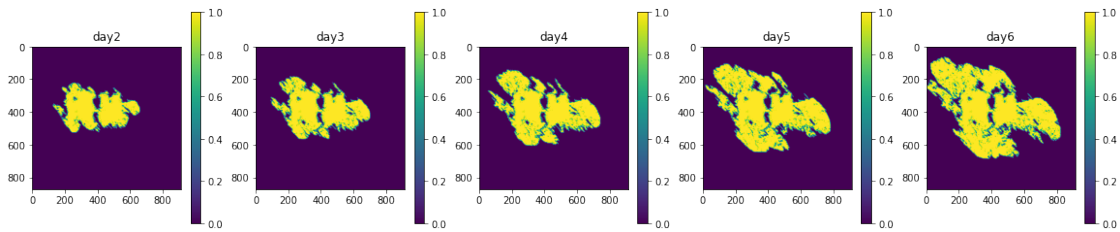
[16]:
```
model_data_compr = encoder.predict(model_data_1D)
satellite_data_compr = encoder.predict(satellite_data_1D)

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 = I * 0.000000001
```

[17]:
```
## 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 )
```

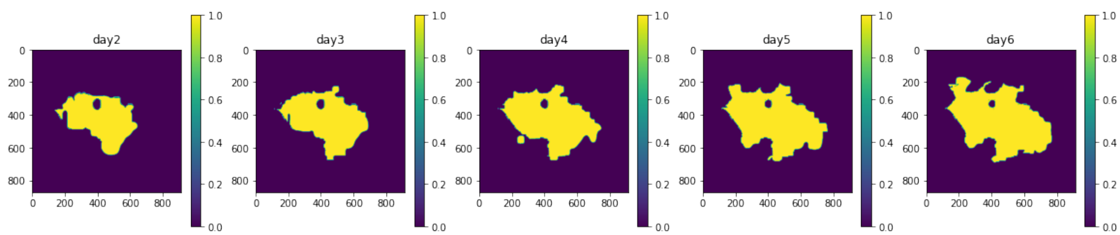
```python
print('MSE after assimilation in latent space: ', mse_after_DA)

## 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:  4188.5737
MSE after assimilation in latent space:  715.8404601641759
MSE before assimilation in physical space:  0.1191695914227833
MSE after assimilation in physical space:  0.08701994260920441
```

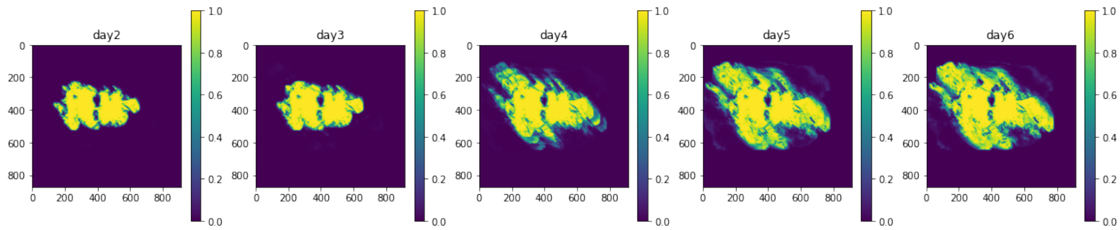
[18]:
```python
# Plot model data
visual.plot_data(model_data)
```



[19]:
```python
# Plot satellite data
visual.plot_data(satellite_data)
```



[20]:
```python
# 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_Nonlinear_Autoencoder.ipynb')
```

```
--2022-03-23 23:29:15--  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

2022-03-23 23:29:15 (46.0 MB/s) - ‘colab_pdf.py’ saved [1864/1864]

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```