

In [1]: `pip install tensorflow`

```
Requirement already satisfied: tensorflow in d:\virtualenv\myenv\lib\site-packages (2.16.1)
Requirement already satisfied: tensorflow-intel==2.16.1 in d:\virtualenv\myenv\lib\site-packages (from tensorflow) (2.16.1)
Requirement already satisfied: absl-py>=1.0.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (2.1.0)
Requirement already satisfied: astunparse>=1.6.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (1.6.3)
Requirement already satisfied: flatbuffers>=23.5.26 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (24.3.25)
Requirement already satisfied: gast!=0.5.0,!0.5.1,!0.5.2,>=0.2.1 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (0.5.4)
Requirement already satisfied: google-pasta>=0.1.1 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (0.2.0)
Requirement already satisfied: h5py>=3.10.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (3.11.0)
Requirement already satisfied: libclang>=13.0.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (18.1.1)
Requirement already satisfied: ml-dtypes~0.3.1 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (0.3.2)
Requirement already satisfied: opt-einsum>=2.3.2 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (3.3.0)
Requirement already satisfied: packaging in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (24.1)
Requirement already satisfied: protobuf!=4.21.0,!4.21.1,!4.21.2,!4.21.3,!4.21.4,!4.21.5,<5.0.0dev,>=3.20.3 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (4.25.3)
Requirement already satisfied: requests<3,>=2.21.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (2.32.3)
Requirement already satisfied: setuptools in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (70.1.0)
Requirement already satisfied: six>=1.12.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (1.16.0)
Requirement already satisfied: termcolor>=1.1.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (2.4.0)
Requirement already satisfied: typing-extensions>=3.6.6 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (4.12.2)
Requirement already satisfied: wrapt>=1.11.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (1.16.0)
Requirement already satisfied: grpcio<2.0,>=1.24.3 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (1.64.1)
Requirement already satisfied: tensorboard<2.17,>=2.16 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (2.16.2)
Requirement already satisfied: keras>=3.0.0 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (3.4.0)
Requirement already satisfied: tensorflow-io-gcs-filesystem>=0.23.1 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (0.31.0)
Requirement already satisfied: numpy<2.0.0,>=1.23.5 in d:\virtualenv\myenv\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (1.26.3)
Requirement already satisfied: wheel<1.0,>=0.23.0 in d:\virtualenv\myenv\lib\site-packages (from astunparse>=1.6.0->tensorflow-intel==2.16.1->tensorflow) (0.43.0)
Requirement already satisfied: rich in d:\virtualenv\myenv\lib\site-packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (13.7.1)
Requirement already satisfied: namex in d:\virtualenv\myenv\lib\site-packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (0.0.8)
Requirement already satisfied: optree in d:\virtualenv\myenv\lib\site-packages (from keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (0.11.0)
Requirement already satisfied: charset-normalizer<4,>=2 in d:\virtualenv\myenv\lib\site-packages (from requests<3,>=2.21.0->tensorflow-intel==2.16.1->tensorflow) (3.3.2)
Requirement already satisfied: idna<4,>=2.5 in d:\virtualenv\myenv\lib\site-packages (from requests<3,>=2.21.0->tensorflow-intel==2.16.1->tensorflow) (3.7)
Requirement already satisfied: urllib3<3,>=1.21.1 in d:\virtualenv\myenv\lib\site-packages (from requests<3,>=2.21.0->tensorflow-intel==2.16.1->tensorflow) (2.2.2)
Requirement already satisfied: certifi>=2017.4.17 in d:\virtualenv\myenv\lib\site-packages (from requests<3,>=2.21.0->tensorflow-intel==2.16.1->tensorflow) (2024.6.2)
Requirement already satisfied: markdown>=2.6.8 in d:\virtualenv\myenv\lib\site-packages (from tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (3.6)
Requirement already satisfied: tensorboard-data-server<0.8.0,>=0.7.0 in d:\virtualenv\myenv\lib\site-packages (from tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (0.7.2)
Requirement already satisfied: werkzeug>=1.0.1 in d:\virtualenv\myenv\lib\site-packages (from tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (3.0.3)
Requirement already satisfied: MarkupSafe>=2.1.1 in d:\virtualenv\myenv\lib\site-packages (from werkzeug>=1.0.1->tensorboard<2.17,>=2.16->tensorflow-intel==2.16.1->tensorflow) (2.1.5)
Requirement already satisfied: markdown-it-py>=2.2.0 in d:\virtualenv\myenv\lib\site-packages (from rich->keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (3.0.0)
Requirement already satisfied: pygments<3.0.0,>=2.13.0 in d:\virtualenv\myenv\lib\site-packages (from rich->keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (2.18.0)
Requirement already satisfied: mdurl~0.1 in d:\virtualenv\myenv\lib\site-packages (from markdown-it-py>=2.2.0->rich->keras>=3.0.0->tensorflow-intel==2.16.1->tensorflow) (0.1.2)
Note: you may need to restart the kernel to use updated packages.
```

```
[notice] A new release of pip is available: 24.1 -> 24.2
[notice] To update, run: python.exe -m pip install --upgrade pip
```

In [2]: `pip install pandas`

```
Requirement already satisfied: pandas in d:\virtualenv\myenv\lib\site-packages (2.2.2)
Requirement already satisfied: numpy>=1.23.2 in d:\virtualenv\myenv\lib\site-packages (from pandas) (1.26.3)
Requirement already satisfied: python-dateutil>=2.8.2 in d:\virtualenv\myenv\lib\site-packages (from pandas) (2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in d:\virtualenv\myenv\lib\site-packages (from pandas) (2024.1)
Requirement already satisfied: tzdata>=2022.7 in d:\virtualenv\myenv\lib\site-packages (from pandas) (2024.1)
Requirement already satisfied: six>=1.5 in d:\virtualenv\myenv\lib\site-packages (from python-dateutil>=2.8.2->pandas) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
[notice] A new release of pip is available: 24.1 -> 24.2
[notice] To update, run: python.exe -m pip install --upgrade pip
```

In [3]: `pip install matplotlib`

```
Requirement already satisfied: matplotlib in d:\virtualenv\myenv\lib\site-packages (3.9.0)
Requirement already satisfied: contourpy>=1.0.1 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (1.2.1)
Requirement already satisfied: cycler>=0.10 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (4.53.0)
Requirement already satisfied: kiwisolver>=1.3.1 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (1.4.5)
Requirement already satisfied: numpy>=1.23 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (1.26.3)
Requirement already satisfied: packaging>=20.0 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (24.1)
Requirement already satisfied: pillow>=8 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (10.2.0)
Requirement already satisfied: pyparsing>=2.3.1 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (3.1.2)
Requirement already satisfied: python-dateutil>=2.7 in d:\virtualenv\myenv\lib\site-packages (from matplotlib) (2.9.0.post0)
Requirement already satisfied: six>=1.5 in d:\virtualenv\myenv\lib\site-packages (from python-dateutil>=2.7->matplotlib) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
[notice] A new release of pip is available: 24.1 -> 24.2
[notice] To update, run: python.exe -m pip install --upgrade pip
```

In [4]: `from tensorflow import keras
import pandas as pd
from matplotlib import pyplot as plt
from config import Config
import os
import numpy as np
from utils import normalize
from custom import CustomLeakyReLU, CustomClippedReLU`

In [5]: `model_path = './models/dl/soc_estimation_dl.keras'
loaded_model = keras.models.load_model(
 model_path,
 custom_objects={
 'CustomLeakyReLU': CustomLeakyReLU,
 'CustomClippedReLU': CustomClippedReLU
 }
)`

In [6]: `config = Config(
 data_dir='./data',
 train_data_subdir='train/',
 val_data_subdir='test/',
 test_data_subdir='test/'
)`

```
data_dir = ['test', 'train', 'val']
train_data_dir = ['TRAIN_LGHG2@n10degC_to_25degC_Norm_5Inputs.csv']
val_data_dir = ['01_TEST_LGHG2@n10degC_Norm_(05_Inputs).csv', '02_TEST_LGHG2@0degC_Norm_(05_Inputs).csv', '03_TEST_LGHG2@10degC_Norm_(05_Inputs).csv', '04_TEST_LGHG2@25degC_Norm_(05_Inputs).csv']
test_data_dir = ['01_TEST_LGHG2@n10degC_Norm_(05_Inputs).csv', '02_TEST_LGHG2@0degC_Norm_(05_Inputs).csv', '03_TEST_LGHG2@10degC_Norm_(05_Inputs).csv', '04_TEST_LGHG2@25degC_Norm_(05_Inputs).csv']
```

In [7]: `test_data_filename = os.listdir(config.get_test_data_dir())[2]
test_data_path = os.path.join(config.get_test_data_dir(), test_data_filename)
test_data = pd.read_csv(test_data_path)
test_data`

```
Out[7]:
```

	V	I	Temp	V_avg	I_avg	SOC
0	0.968019	0.749112	0.521236	0.968019	0.749112	1.000000
1	0.965316	0.747098	0.521236	0.966668	0.748105	0.999990
2	0.965198	0.746992	0.521236	0.966178	0.747734	0.999983
3	0.964961	0.747098	0.518403	0.965874	0.747575	0.999973
4	0.964961	0.747098	0.518403	0.965691	0.747480	0.999963
...	...	...	...	...	...	...
44279	0.335128	0.751020	0.532568	0.329741	0.751020	0.194990
44280	0.335128	0.751020	0.532568	0.329778	0.751020	0.194990
44281	0.335128	0.751020	0.532568	0.329815	0.751020	0.194990
44282	0.335128	0.751020	0.532568	0.329851	0.751020	0.194990
44283	0.335128	0.751020	0.532568	0.329888	0.751020	0.194990

44284 rows × 6 columns

```
In [8]: X_test = test_data[['V', 'I', 'Temp', 'V_avg', 'I_avg']].values
X_test.shape
```

```
Out[8]: (44284, 5)
```

```
In [9]: X_test
```

```
Out[9]: array([[0.96801895, 0.74911237, 0.52123591, 0.96801895, 0.74911237],
 [0.96531628, 0.7470984 , 0.52123591, 0.96666762, 0.74810539],
 [0.96519787, 0.74699221, 0.52123591, 0.9661777 , 0.74773433],
 ...,
 [0.33512765, 0.75102009, 0.53256776, 0.32981484, 0.75102009],
 [0.33512765, 0.75102009, 0.53256776, 0.32985141, 0.75102009],
 [0.33512765, 0.75102009, 0.53256776, 0.3298875 , 0.75102009]])
```

```
In [10]: normalized_X_test = normalize(X_test)
normalized_X_test
```

```
Out[10]: array([[ 1.          ,  0.02007657, -1.          ,  1.          ,  0.02007657],
 [ 0.99393247,  0.01412849, -1.          ,  1.          ,  0.01864986],
 [ 0.99559568,  0.01476778, -1.          ,  1.          ,  0.01810358],
 ...,
 [-0.97477332,  1.          , -0.0372726 , -1.          ,  1.          ],
 [-0.97494477,  1.          , -0.03736266, -1.          ,  1.          ],
 [-0.97511403,  1.          , -0.03745156, -1.          ,  1.          ]])
```

```
In [11]: y_test = test_data['SOC'].values
y_test.shape
```

```
Out[11]: (44284,)
```

```
In [12]: y_test
```

```
Out[12]: array([1.          , 0.99999   , 0.99998333, ..., 0.19499   , 0.19499   ,
 0.19499   ])
```

```
In [13]: soc_observed = y_test

soc_predicted = loaded_model.predict(normalized_X_test)
soc_predicted
```

1384/1384 ————— 3s 816us/step

```
Out[13]: array([[0.9936495 ],
 [0.99297535],
 [0.9933429 ],
 ...,
 [0.20909834],
 [0.20913501],
 [0.20917141]], dtype=float32)
```

```
In [14]: results = loaded_model.evaluate(normalized_X_test, y_test)
```

1384/1384 ————— 2s 1ms/step - loss: 0.0054

```
In [15]: from utils import rmse, maxv, mae
```

```

rmse_value = rmse(soc_observed, soc_predicted)
print(f'rmse(observed, predicted) = {round(rmse_value*100,2)}%')
max_value = maxv(soc_observed, soc_predicted)
print(f'max(observed, predicted) = {round(max_value*100,2)}%')
mae_value = mae(soc_observed, soc_predicted)
print(f'mae(observed, predicted) = {round(mae_value*100,2)}%')

```

```

rmse(observed, predicted) = 6.49%
max(observed, predicted) = 27.35%
mae(observed, predicted) = 4.48%

```

In [26]: `fig, axes = plt.subplots(nrows=2, ncols=1, figsize=(11, 6))`

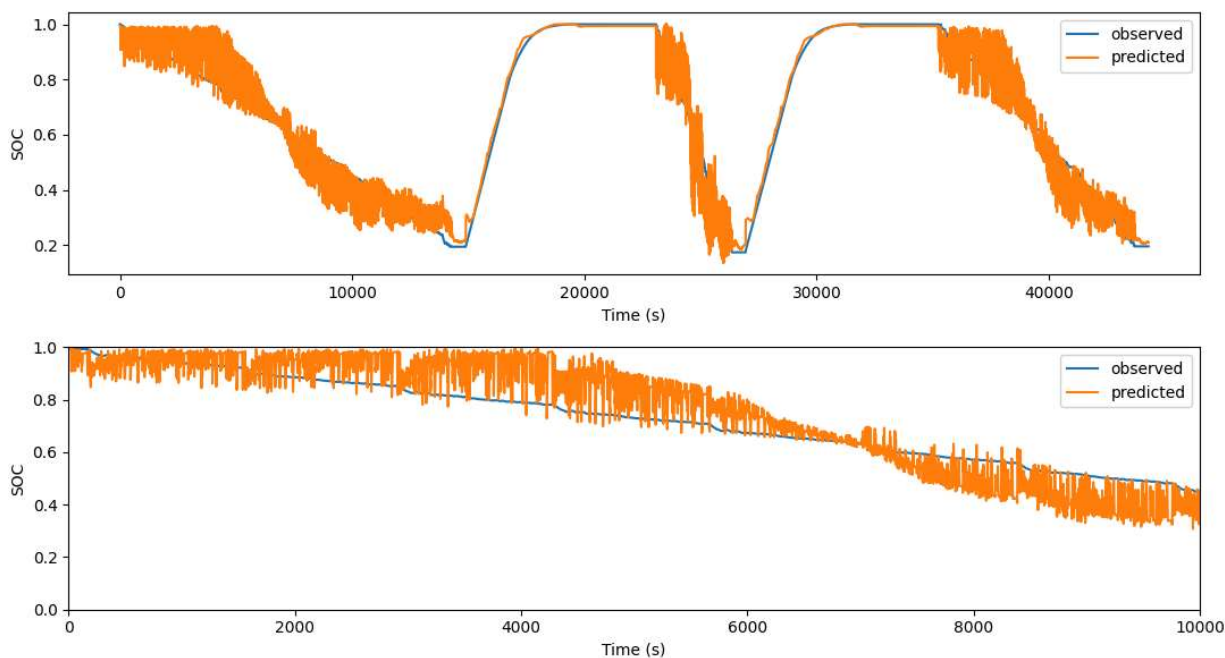
```

axes[0].plot(soc_observed, label='observed')
axes[0].plot(soc_predicted, label='predicted')
axes[0].set_ylabel('SOC')
axes[0].set_xlabel('Time (s)')
axes[0].legend()

axes[1].plot(soc_observed, label='observed')
axes[1].plot(soc_predicted, label='predicted')
axes[1].set_ylabel('SOC')
axes[1].set_xlabel('Time (s)')
axes[1].legend()
axes[1].axis([0, 10000, 0, 1])

plt.tight_layout()
plt.show()

```



In [24]:

```

abs_err = []
for i in range(len(soc_observed)):
    socp = soc_predicted[i]
    socio = soc_observed[i]
    diff = socp - socio
    abs_err.append(diff)

plt.figure(figsize=(11,3))
plt.plot(abs_err, label='abs_err')
plt.ylabel('Absolute Error')
plt.xlabel('Time (s)')
plt.legend()
plt.tight_layout()
plt.show()

```

