PS19

January 26, 2024

1 Mini-project #2 (RNN exercise)

1.1 Task: Weather prediction

1.2 Jena climate dataset

This dataset is prepared by Max Planck Institute for Biogeochemistry. It is measured in Jena, Germany, from Jan. 10 2009 to December 31 2016.

1.3 Loading Jena climate dataset

[1]:

```
import pandas as pd
```

[2]:

```
data = pd.read_csv('jena_climate_2009_2016.csv')
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 420551 entries, 0 to 420550
Data columns (total 15 columns):
 #   Column           Non-Null Count   Dtype
---  ------           --------------   -----
 0   Date Time        420551 non-null  object
 1   p (mbar)         420551 non-null  float64
 2   T (degC)         420551 non-null  float64
 3   Tpot (K)         420551 non-null  float64
 4   Tdew (degC)      420551 non-null  float64
 5   rh (%)           420551 non-null  float64
 6   VPmax (mbar)     420551 non-null  float64
 7   VPact (mbar)     420551 non-null  float64
 8   VPdef (mbar)     420551 non-null  float64
 9   sh (g/kg)        420551 non-null  float64
 10  H2OC (mmol/mol)  420551 non-null  float64
 11  rho (g/m**3)     420551 non-null  float64
 12  wv (m/s)         420551 non-null  float64
 13  max. wv (m/s)    420551 non-null  float64
 14  wd (deg)         420551 non-null  float64
dtypes: float64(14), object(1)
memory usage: 48.1+ MB
```

1.3.1 Temperatures

`T (degC)`: Temperature in Celsius
`Tpot (K)`: Temperature in Kelvin

1.3.2 Others

`p (mbar)`: The pascal SI derived unit of pressure
`Tdew (degC)`: Temperature in Celsius relative to humidity ( )
`rh (%)`: Relative humidity is a measure of how saturated the air is with waver vapor ( )
`VPmax (mbar)`: Saturation vapor pressure ( )
`VPact (mbar)`: Vapor pressure ( )
`VPdef (mbar)`: Vapor pressure deficit
`sh (g/kg)`: Specific humidity ( )
`H2OC (mmol/mol)`: Water vapor concentration ( )
`rho (g/m**3)`: Airtight
`wv (m/s)`: Wind speed
`max. wv (m/s)`: Maximimum wind speed
`wd (deg)`: Wind direction in degrees

[3]:

```
# Look up the first five examples
data.head(5)
```

[3]:

```
             Date Time  p (mbar)  T (degC)  Tpot (K)  Tdew (degC)  rh (%)  \
0  01.01.2009 00:10:00    996.52     -8.02    265.40        -8.90    93.3
1  01.01.2009 00:20:00    996.57     -8.41    265.01        -9.28    93.4
2  01.01.2009 00:30:00    996.53     -8.51    264.91        -9.31    93.9
3  01.01.2009 00:40:00    996.51     -8.31    265.12        -9.07    94.2
4  01.01.2009 00:50:00    996.51     -8.27    265.15        -9.04    94.1

   VPmax (mbar)  VPact (mbar)  VPdef (mbar)  sh (g/kg)  H2OC (mmol/mol)  \
0          3.33          3.11          0.22       1.94             3.12
1          3.23          3.02          0.21       1.89             3.03
2          3.21          3.01          0.20       1.88             3.02
3          3.26          3.07          0.19       1.92             3.08
4          3.27          3.08          0.19       1.92             3.09

   rho (g/m**3)  wv (m/s)  max. wv (m/s)  wd (deg)
0       1307.75      1.03           1.75     152.3
1       1309.80      0.72           1.50     136.1
2       1310.24      0.19           0.63     171.6
3       1309.19      0.34           0.50     198.0
4       1309.00      0.32           0.63     214.3
```

1.4 Data visualization: Temperature in celsius

[4]:

```
T_data = data['T (degC)']
date_time = pd.to_datetime(data['Date Time'],format='%d.%m.%Y %H:%M:%S')
```

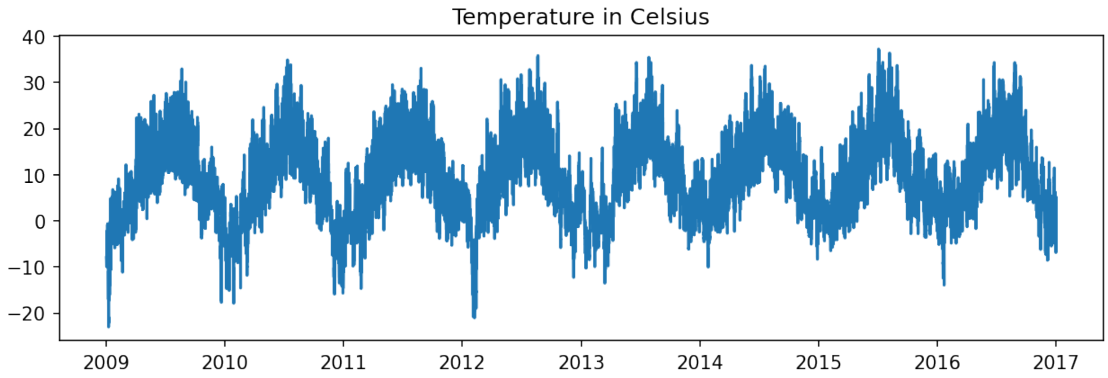
[5]:

```
print(T_data)
print(T_data.shape)
print(date_time)
```

```
0        -8.02
1        -8.41
2        -8.51
3        -8.31
4        -8.27
          …
420546   -4.05
420547   -3.35
420548   -3.16
420549   -4.23
420550   -4.82
Name: T (degC), Length: 420551, dtype: float64
(420551,)
0        2009-01-01 00:10:00
1        2009-01-01 00:20:00
2        2009-01-01 00:30:00
3        2009-01-01 00:40:00
4        2009-01-01 00:50:00
                 …
420546   2016-12-31 23:20:00
420547   2016-12-31 23:30:00
420548   2016-12-31 23:40:00
420549   2016-12-31 23:50:00
420550   2017-01-01 00:00:00
Name: Date Time, Length: 420551, dtype: datetime64[ns]
```

[6]:

```
import matplotlib.pyplot as plt

plt.figure(figsize=(10,3), dpi=150)
plt.plot(date_time, T_data)
plt.title('Temperature in Celsius')
plt.show()
```



1.5 Correlation analysis

We employ Pearson correlation defined as:

$$\rho_{ij} := \frac{\mathsf{Cov}(x_i, x_j)}{\sqrt{\mathsf{Var}(x_i)\mathsf{Var}(x_j)}}.$$

It is in between -1 and 1.

[7]:

```
data.corr()
```

[7]:

```
                  p (mbar)  T (degC)  Tpot (K)  Tdew (degC)    rh (%)  \
p (mbar)          1.000000 -0.045375 -0.124718    -0.066755 -0.018352
T (degC)         -0.045375  1.000000  0.996827     0.895708 -0.572416
Tpot (K)         -0.124718  0.996827  1.000000     0.894911 -0.567127
Tdew (degC)      -0.066755  0.895708  0.894911     1.000000 -0.156615
rh (%)           -0.018352 -0.572416 -0.567127    -0.156615  1.000000
VPmax (mbar)     -0.031546  0.951113  0.947293     0.799271 -0.615842
VPact (mbar)     -0.054370  0.867673  0.866205     0.968344 -0.151494
VPdef (mbar)     -0.003401  0.761744  0.756962     0.435752 -0.843835
sh (g/kg)        -0.069762  0.866755  0.866533     0.967599 -0.150841
H2OC (mmol/mol) -0.069804  0.867177  0.866955     0.968044 -0.150969
rho (g/m**3)      0.307640 -0.963410 -0.981345    -0.885232  0.514282
wv (m/s)         -0.005701 -0.004689 -0.004195    -0.008718 -0.005020
max. wv (m/s)    -0.007760 -0.002871 -0.002224    -0.009091 -0.009921
wd (deg)         -0.063258  0.038732  0.043599     0.049877 -0.015912

                  VPmax (mbar)  VPact (mbar)  VPdef (mbar)  sh (g/kg)  \
p (mbar)            -0.031546     -0.054370     -0.003401  -0.069762
T (degC)             0.951113      0.867673      0.761744   0.866755
Tpot (K)             0.947293      0.866205      0.756962   0.866533
Tdew (degC)          0.799271      0.968344      0.435752   0.967599
rh (%)              -0.615842     -0.151494     -0.843835  -0.150841
VPmax (mbar)         1.000000      0.824865      0.875588   0.824460
```

```
VPact (mbar)         0.824865      1.000000      0.449154   0.999851
VPdef (mbar)         0.875588      0.449154      1.000000   0.448641
sh (g/kg)            0.824460      0.999851      0.448641   1.000000
H2OC (mmol/mol)      0.824493      0.999856      0.448689   0.999997
rho (g/m**3)        -0.901536     -0.850241     -0.698290  -0.853325
wv (m/s)            -0.004018     -0.009600      0.001852  -0.009479
max. wv (m/s)       -0.002213     -0.010316      0.005317  -0.010163
wd (deg)            -0.009583      0.018418     -0.030881   0.019376

                 H2OC (mmol/mol)  rho (g/m**3)  wv (m/s)  max. wv (m/s)  \
p (mbar)               -0.069804      0.307640 -0.005701      -0.007760
T (degC)                0.867177     -0.963410 -0.004689      -0.002871
Tpot (K)                0.866955     -0.981345 -0.004195      -0.002224
Tdew (degC)             0.968044     -0.885232 -0.008718      -0.009091
rh (%)                 -0.150969      0.514282 -0.005020      -0.009921
VPmax (mbar)            0.824493     -0.901536 -0.004018      -0.002213
VPact (mbar)            0.999856     -0.850241 -0.009600      -0.010316
VPdef (mbar)            0.448689     -0.698290  0.001852       0.005317
sh (g/kg)               0.999997     -0.853325 -0.009479      -0.010163
H2OC (mmol/mol)         1.000000     -0.853769 -0.009477      -0.010158
rho (g/m**3)           -0.853769      1.000000  0.003240       0.001086
wv (m/s)               -0.009477      0.003240  1.000000       0.948477
max. wv (m/s)          -0.010158      0.001086  0.948477       1.000000
wd (deg)                0.019607     -0.058072 -0.015322      -0.014471

                 wd (deg)
p (mbar)        -0.063258
T (degC)         0.038732
Tpot (K)         0.043599
Tdew (degC)      0.049877
rh (%)          -0.015912
VPmax (mbar)    -0.009583
VPact (mbar)     0.018418
VPdef (mbar)    -0.030881
sh (g/kg)        0.019376
H2OC (mmol/mol)  0.019607
rho (g/m**3)    -0.058072
wv (m/s)        -0.015322
max. wv (m/s)   -0.014471
wd (deg)         1.000000
```

1.6 Statistics of data

```
[8]: data.describe()
```

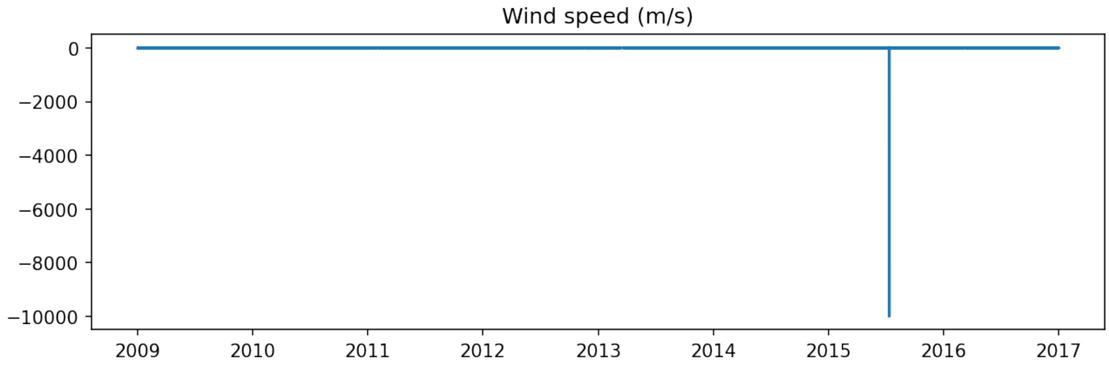
```
[8]:            p (mbar)       T (degC)       Tpot (K)    Tdew (degC)  \
     count  420551.000000  420551.000000  420551.000000  420551.000000
```

```
mean      989.212776       9.450147     283.492743       4.955854
std         8.358481       8.423365       8.504471       6.730674
min       913.600000     -23.010000     250.600000     -25.010000
25%       984.200000       3.360000     277.430000       0.240000
50%       989.580000       9.420000     283.470000       5.220000
75%       994.720000      15.470000     289.530000      10.070000
max      1015.350000      37.280000     311.340000      23.110000

              rh (%)   VPmax (mbar)   VPact (mbar)   VPdef (mbar)  \
count  420551.000000  420551.000000  420551.000000  420551.000000
mean       76.008259      13.576251       9.533756       4.042412
std        16.476175       7.739020       4.184164       4.896851
min        12.950000       0.950000       0.790000       0.000000
25%        65.210000       7.780000       6.210000       0.870000
50%        79.300000      11.820000       8.860000       2.190000
75%        89.400000      17.600000      12.350000       5.300000
max       100.000000      63.770000      28.320000      46.010000

           sh (g/kg)  H2OC (mmol/mol)   rho (g/m**3)       wv (m/s)  \
count  420551.000000    420551.000000  420551.000000  420551.000000
mean        6.022408         9.640223    1216.062748       1.702224
std         2.656139         4.235395      39.975208      65.446714
min         0.500000         0.800000    1059.450000   -9999.000000
25%         3.920000         6.290000    1187.490000       0.990000
50%         5.590000         8.960000    1213.790000       1.760000
75%         7.800000        12.490000    1242.770000       2.860000
max        18.130000        28.820000    1393.540000      28.490000

       max. wv (m/s)       wd (deg)
count  420551.000000  420551.000000
mean        3.056555     174.743738
std        69.016932      86.681693
min     -9999.000000       0.000000
25%         1.760000     124.900000
50%         2.960000     198.100000
75%         4.740000     234.100000
max        23.500000     360.000000
```

1.7 Missing entries in wind speed (m/s)

[9]:

```
import matplotlib.pyplot as plt

plt.figure(figsize=(10,3), dpi=150)
wv = data['wv (m/s)']
plt.plot(date_time, wv)
plt.title('Wind speed (m/s)')
plt.show()
```



1.8 Data preprocessing

Wind speed (and maximum wind speed) is set to `-9999.00` for missing entries. Let us fill up the missing entries with the mean.

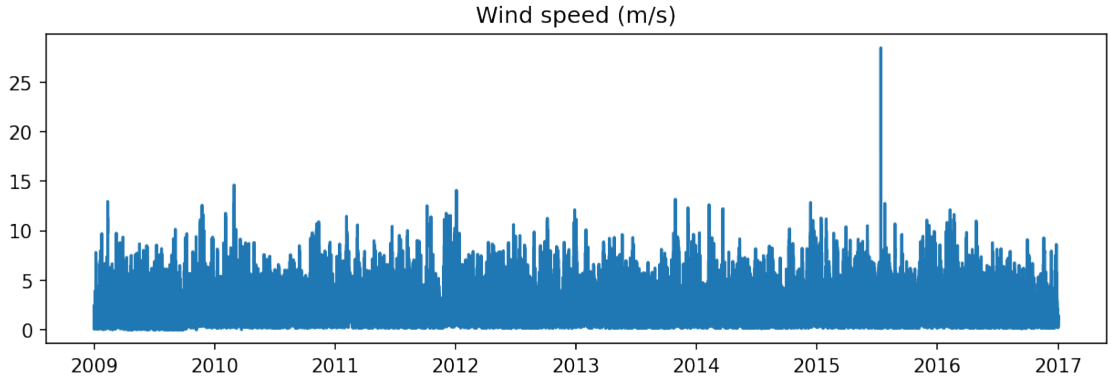
[10]:
```
wv = data['wv (m/s)']
wv_missing_idx = (wv == -9999.00)
wv_mean = wv[~wv_missing_idx].mean()
wv[wv_missing_idx] = wv_mean
```

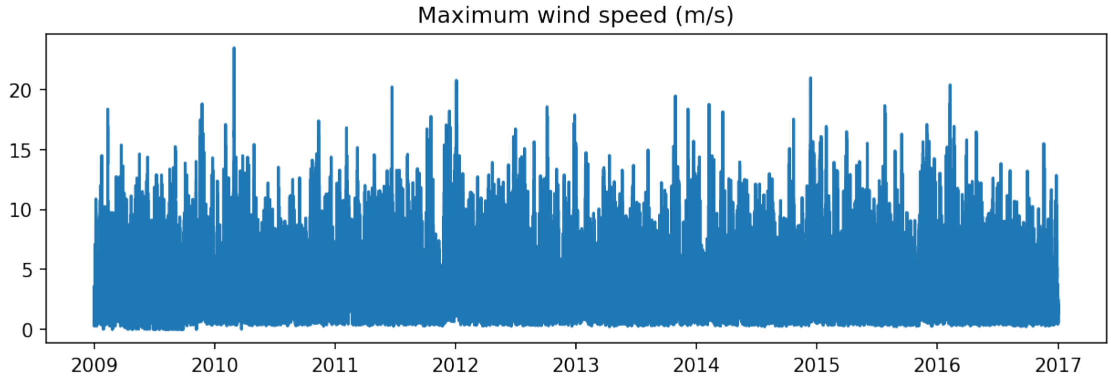
```
C:\Users\chsuh\AppData\Local\Temp\ipykernel_41920\832945953.py:4:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  wv[wv_missing_idx] = wv_mean
```

[11]:
```
max_wv = data['max. wv (m/s)']
missing_idx = (max_wv == -9999.00)
max_wv_mean = max_wv[~missing_idx].mean()
max_wv[missing_idx] = max_wv_mean
```

```
C:\Users\chsuh\AppData\Local\Temp\ipykernel_41920\1423667913.py:4:
SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  max_wv[missing_idx] = max_wv_mean
```

[12]:
```
import matplotlib.pyplot as plt

plt.figure(figsize=(10,3), dpi=150)
plt.plot(date_time, wv)
plt.title('Wind speed (m/s)')
plt.show()

plt.figure(figsize=(10,3), dpi=150)
plt.plot(date_time, max_wv)
plt.title('Maximum wind speed (m/s)')
plt.show()
```





1.9 Check if missing entries are properly filled up

[13]:
```
data.describe()
```

[13]:
```
              p (mbar)       T (degC)       Tpot (K)     Tdew (degC)  \
count  420551.000000  420551.000000  420551.000000  420551.000000
mean      989.212776       9.450147     283.492743       4.955854
std         8.358481       8.423365       8.504471       6.730674
min       913.600000     -23.010000     250.600000     -25.010000
25%       984.200000       3.360000     277.430000       0.240000
50%       989.580000       9.420000     283.470000       5.220000
```

```
75%       994.720000      15.470000     289.530000      10.070000
max      1015.350000      37.280000     311.340000      23.110000

              rh (%)   VPmax (mbar)   VPact (mbar)   VPdef (mbar)  \
count  420551.000000  420551.000000  420551.000000  420551.000000
mean       76.008259      13.576251       9.533756       4.042412
std        16.476175       7.739020       4.184164       4.896851
min        12.950000       0.950000       0.790000       0.000000
25%        65.210000       7.780000       6.210000       0.870000
50%        79.300000      11.820000       8.860000       2.190000
75%        89.400000      17.600000      12.350000       5.300000
max       100.000000      63.770000      28.320000      46.010000

           sh (g/kg)  H2OC (mmol/mol)   rho (g/m**3)       wv (m/s)  \
count  420551.000000    420551.000000  420551.000000  420551.000000
mean        6.022408         9.640223    1216.062748       2.130282
std         2.656139         4.235395      39.975208       1.542271
min         0.500000         0.800000    1059.450000       0.000000
25%         3.920000         6.290000    1187.490000       0.990000
50%         5.590000         8.960000    1213.790000       1.760000
75%         7.800000        12.490000    1242.770000       2.860000
max        18.130000        28.820000    1393.540000      28.490000

       max. wv (m/s)       wd (deg)
count  420551.000000  420551.000000
mean        3.532242     174.743738
std         2.340355      86.681693
min         0.000000       0.000000
25%         1.760000     124.900000
50%         2.960000     198.100000
75%         4.740000     234.100000
max        23.500000     360.000000
```

1.10 Remove date_time column

[14]:

```
data.pop('Date Time')
data
```

[14]:

```
        p (mbar)  T (degC)  Tpot (K)  Tdew (degC)  rh (%)  VPmax (mbar)  \
0         996.52     -8.02    265.40        -8.90   93.30          3.33
1         996.57     -8.41    265.01        -9.28   93.40          3.23
2         996.53     -8.51    264.91        -9.31   93.90          3.21
3         996.51     -8.31    265.12        -9.07   94.20          3.26
4         996.51     -8.27    265.15        -9.04   94.10          3.27
…          …       …       …          …     …           …
420546   1000.07     -4.05    269.10        -8.13   73.10          4.52
420547    999.93     -3.35    269.81        -8.06   69.71          4.77
```

```
420548    999.82     -3.16    270.01        -8.21   67.91           4.84
420549    999.81     -4.23    268.94        -8.53   71.80           4.46
420550    999.82     -4.82    268.36        -8.42   75.70           4.27

        VPact (mbar)  VPdef (mbar)  sh (g/kg)  H2OC (mmol/mol)  rho (g/m**3)  \
0               3.11          0.22       1.94             3.12       1307.75
1               3.02          0.21       1.89             3.03       1309.80
2               3.01          0.20       1.88             3.02       1310.24
3               3.07          0.19       1.92             3.08       1309.19
4               3.08          0.19       1.92             3.09       1309.00
…              …            …         …               …            …
420546          3.30          1.22       2.06             3.30       1292.98
420547          3.32          1.44       2.07             3.32       1289.44
420548          3.28          1.55       2.05             3.28       1288.39
420549          3.20          1.26       1.99             3.20       1293.56
420550          3.23          1.04       2.01             3.23       1296.38

        wv (m/s)  max. wv (m/s)  wd (deg)
0           1.03           1.75     152.3
1           0.72           1.50     136.1
2           0.19           0.63     171.6
3           0.34           0.50     198.0
4           0.32           0.63     214.3
…          …             …        …
420546      0.67           1.52     240.0
420547      1.14           1.92     234.3
420548      1.08           2.00     215.2
420549      1.49           2.16     225.8
420550      1.23           1.96     184.9

[420551 rows x 14 columns]
```

```
[ ]:
```

```
[ ]:
```

```
[ ]:
```