IFN646 - Biomedical Data Science — Wearables Project

Import of necessary packages

In [1]:
```
import matplotlib.pyplot as plt
import numpy
import seaborn as sns
import pandas as pd
from sklearn.metrics import confusion_matrix, f1_score, accuracy_score, precision_score, recall_score
from preprocess import load_data, inform, __handle_missing_values
import warnings

# create image directory
from pathlib import Path
Path("img").mkdir(parents=True, exist_ok=True)
warnings.filterwarnings('ignore')
```

Load the data

In [2]:
```
full, train, test = load_data()
```

```
Loading cached files.
```

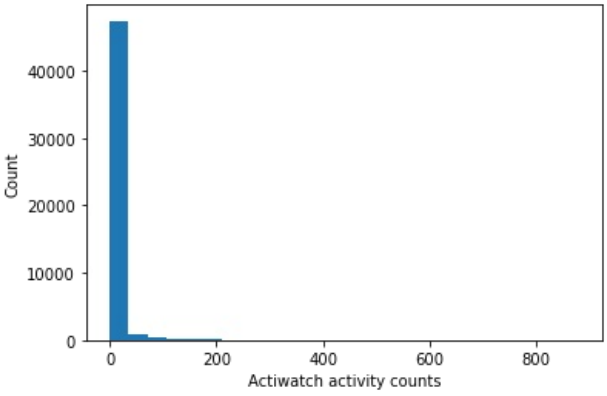
Print statistics of the datasets

In [3]:
```
print("Full data:")
inform(full)
print("Training data:")
inform(train)
print("Test data:")
inform(test)
```

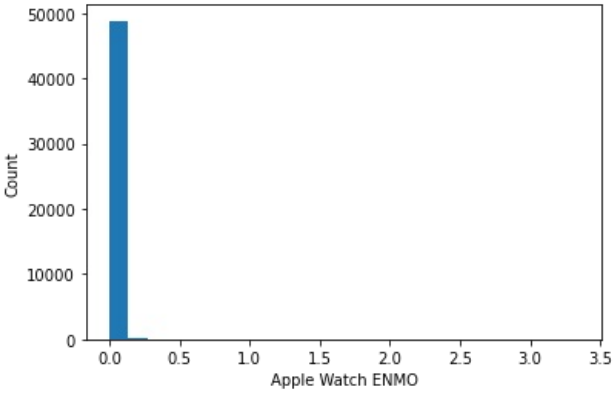
```
Full data:
Shape of data: (49100, 5)
There are 90.74% 0 values in column 'Actiware classification'.
There are 92.14 0 values in column 'Actiwatch activity counts'.
Training data:
Shape of data: (40761, 5)
There are 91.03% 0 values in column 'Actiware classification'.
There are 92.13 0 values in column 'Actiwatch activity counts'.
Test data:
Shape of data: (8339, 5)
There are 89.29% 0 values in column 'Actiware classification'.
There are 92.18 0 values in column 'Actiwatch activity counts'.
```

Gain overview of data

In [4]:
```
# plot histogram of Actiwatch activity counts for the whole data set
plt.hist(full['Actiwatch activity counts'], bins=25)
plt.ylabel('Count')
plt.xlabel('Actiwatch activity counts');
plt.savefig('img/actiwatch_histogram.pdf', bbox='tight')
```



In [5]:
```
# plot histogram of Apple Watch ENMO for the whole data set
plt.hist(full['Apple Watch ENMO'], bins=25)
plt.ylabel('Count')
plt.xlabel('Apple Watch ENMO');
plt.savefig('img/apple_watch_histogram.pdf', bbox='tight')
```



Function to calculate total counts according to Philips' Actiware software specification

In [6]:
```
def total_counts(df, src_col, dest_col):
    day = df['day'].values
    cts = df[src_col].values
    total = []
    for i in range(len(cts)):
        div_by_25_sum = 0
        div_by_5_sum = 0
        for j in range(-8, -4):
            if i + j >= 0 and day[i + j] == day[i]:
                div_by_25_sum += cts[i + j]
        for j in range(-4, 0):
            if i + j >= 0 and day[i + j] == day[i]:
                div_by_5_sum += cts[i + j]
        for j in range(1, 5):
            if i + j < len(cts) and day[i + j] == day[i]:
                div_by_5_sum += cts[i + j]
        for j in range(5, 9):
            if i + j < len(cts) and day[i + j] == day[i]:
                div_by_25_sum += cts[i + j]
        calculation = 0.04 * div_by_25_sum + 0.20 * div_by_5_sum + 4.00 * cts[i]
        total.append(calculation)
    df[dest_col] = total
```

In [7]:
```
# call total_counts function and add a column for total counts from Actiwatch
total_counts(train, 'Actiwatch activity counts', 'Actiwatch Total Counts')

# print first 30 items
train.head(30)
```

Out[7]:

	day	Actiwatch activity counts	Actiware classification	Apple Watch ENMO	time	Actiwatch Total Counts
1	1	109.0	1.0	0.227648	20:58:15	555.20
2	1	170.0	1.0	0.217089	20:58:30	812.40
3	1	91.0	1.0	0.267528	20:58:45	548.68
4	1	101.0	1.0	0.222397	20:59:00	607.12
5	1	125.0	1.0	0.262205	20:59:15	727.64
6	1	105.0	1.0	0.283417	20:59:30	673.96
7	1	176.0	1.0	0.314253	20:59:45	954.84
8	1	105.0	1.0	0.328872	21:00:00	689.72
9	1	159.0	1.0	0.444264	21:00:15	897.32
10	1	215.0	1.0	0.521921	21:00:30	1110.12
11	1	208.0	1.0	0.515725	21:00:45	1095.32
12	1	91.0	1.0	0.318492	21:01:00	637.72
13	1	97.0	1.0	0.348385	21:01:15	651.84
14	1	134.0	1.0	0.301678	21:01:30	773.68
15	1	125.0	1.0	0.292101	21:01:45	762.48
16	1	117.0	1.0	0.306116	21:02:00	692.08
17	1	76.0	1.0	0.273415	21:02:15	517.52
18	1	73.0	1.0	0.242683	21:02:30	484.24
19	1	385.0	1.0	0.276460	21:02:45	1639.80
20	1	2.0	1.0	0.004816	21:03:00	156.08
21	1	0.0	1.0	0.002099	21:03:15	126.12
22	1	0.0	1.0	0.002393	21:03:30	110.08
23	1	0.0	1.0	0.002089	21:03:45	93.04
24	1	0.0	1.0	0.002052	21:04:00	26.44
25	1	0.0	1.0	0.001939	21:04:15	21.44
26	1	0.0	1.0	0.001993	21:04:30	18.40
27	1	0.0	1.0	0.002051	21:04:45	15.48
28	1	0.0	1.0	0.001956	21:05:00	0.08
29	1	0.0	1.0	0.002015	21:05:15	0.00
30	1	0.0	1.0	0.001976	21:05:30	0.00

Helper functions that classifies into sleep/wake according to threshold 40

In [8]:

```
def classify(row, col):
    if row[col] > 40:
        return 1
    else:
        return 0
```

Plausibility Check

Perform classification of actiwatch total counts for plausibility check

In [9]:

```
train['Actiware classification calculated'] = train.apply(lambda x: classify(x, 'Actiwatch Total Counts'), axis

# set uninterrupted sleep values
train = __handle_missing_values(train, 'Actiware classification calculated')

#print first 30 elements
train.head(30)
```

```
0 rows were dropped where both activity counts and classification were missing.
That is roughly 0.00% of the dataset.

1125 classifications were set to 1 for the first and last 5 minutes of uninterrupted sleep.
That is roughly 2.76% of the dataset.
```

Out[9]:

	day	Actiwatch activity counts	Actiware classification	Apple Watch ENMO	time	Actiwatch Total Counts	Actiware classification calculated
1	1	109.0	1.0	0.227648	20:58:15	555.20	1
2	1	170.0	1.0	0.217089	20:58:30	812.40	1
3	1	91.0	1.0	0.267528	20:58:45	548.68	1
4	1	101.0	1.0	0.222397	20:59:00	607.12	1
5	1	125.0	1.0	0.262205	20:59:15	727.64	1
6	1	105.0	1.0	0.283417	20:59:30	673.96	1
7	1	176.0	1.0	0.314253	20:59:45	954.84	1
8	1	105.0	1.0	0.328872	21:00:00	689.72	1
9	1	159.0	1.0	0.444264	21:00:15	897.32	1
10	1	215.0	1.0	0.521921	21:00:30	1110.12	1
11	1	208.0	1.0	0.515725	21:00:45	1095.32	1
12	1	91.0	1.0	0.318492	21:01:00	637.72	1
13	1	97.0	1.0	0.348385	21:01:15	651.84	1
14	1	134.0	1.0	0.301678	21:01:30	773.68	1
15	1	125.0	1.0	0.292101	21:01:45	762.48	1
16	1	117.0	1.0	0.306116	21:02:00	692.08	1
17	1	76.0	1.0	0.273415	21:02:15	517.52	1
18	1	73.0	1.0	0.242683	21:02:30	484.24	1
19	1	385.0	1.0	0.276460	21:02:45	1639.80	1
20	1	2.0	1.0	0.004816	21:03:00	156.08	1
21	1	0.0	1.0	0.002099	21:03:15	126.12	1
22	1	0.0	1.0	0.002393	21:03:30	110.08	1
23	1	0.0	1.0	0.002089	21:03:45	93.04	1
24	1	0.0	1.0	0.002052	21:04:00	26.44	1
25	1	0.0	1.0	0.001939	21:04:15	21.44	1
26	1	0.0	1.0	0.001993	21:04:30	18.40	1
27	1	0.0	1.0	0.002051	21:04:45	15.48	1
28	1	0.0	1.0	0.001956	21:05:00	0.08	1
29	1	0.0	1.0	0.002015	21:05:15	0.00	1
30	1	0.0	1.0	0.001976	21:05:30	0.00	1

Compare classification to calculated classification

In [10]:

```
classification_stats = train.groupby(["Actiware classification", "Actiware classification calculated"]).size()
print(classification_stats)
```

```
Actiware classification  Actiware classification calculated
0.0                      0                                    37106
1.0                      0                                       19
                         1                                     3632
dtype: int64
```

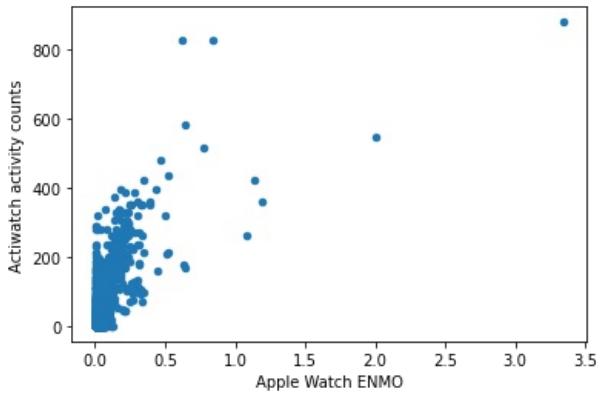
The plausibility check in which we re-classified the sleep/wake state according to Philip's software specification almost yielded a perfect result. Merely 19 values are misclassified. This might be due to some NA values handled improperly or a bug in the uninterrupted sleep algorithm. We will investigate that further in the next iteration.

Fit Machine Learning Model

Draw scatter plot from Apple Watch and Actiwatch

In [11]:

```
train.plot.scatter(x='Apple Watch ENMO', y='Actiwatch activity counts')
plt.savefig('img/scatter_plot.pdf', bbox='tight')
```

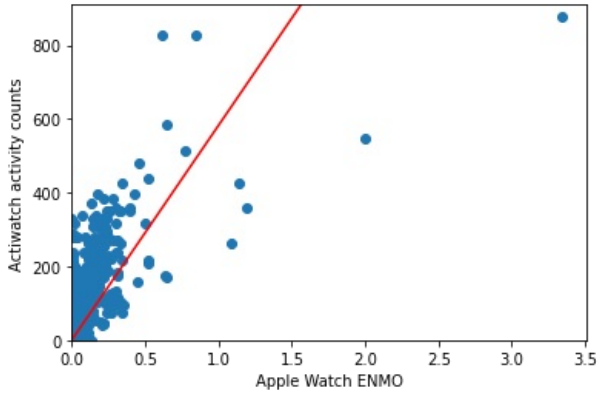


Fit linear Regression Model

In [12]:

```
# declare x and y for the model
x = train['Apple Watch ENMO']
y = train['Actiwatch activity counts']

x.fillna(0, inplace=True)

# fit linear model
model = numpy.poly1d(numpy.polyfit(x, y, 1))

# create linspace to draw scatter plot in next step
line = numpy.linspace(0, 3.5, 1000)

# scatter plot
plt.scatter(x, y)

# draw regression graph into plot
plt.plot(line, model(line), color='red')

# set limits
plt.xlim([0,3.51])
plt.ylim([0,910])

# set labels
plt.xlabel("Apple Watch ENMO")
plt.ylabel("Actiwatch activity counts")

plt.savefig('img/scatter_plot_with_regression_line.pdf', bbox='tight')

print('The function of the regression line is:\nf(x) =', str(model).strip())
```

```
The function of the regression line is:
f(x) = 582.3 x + 0.2081
```



Predict if sleep or awake for test data

In [13]:

```
# predict activity counts
test['Predicted activity counts'] = model(test['Apple Watch ENMO'])

# calculate total counts from prediction
total_counts(test, 'Predicted activity counts', 'Predicted Total Counts')

# print first 15 rows
test.head(15)
```

Out[13]:

	day	Actiwatch activity counts	Actiware classification	Apple Watch ENMO	time	Predicted activity counts	Predicted Total Counts
7789	5	91.0	1.0	0.049485	22:11:15	29.023007	317.353564
7790	5	62.0	1.0	0.047339	22:11:30	27.773589	323.652867
7791	5	58.0	1.0	0.069403	22:11:45	40.621203	379.619787
7792	5	154.0	1.0	1.066049	22:12:00	620.965014	2585.415302
7793	5	164.0	1.0	0.503060	22:12:15	293.138021	1340.419208
7794	5	159.0	1.0	0.117267	22:12:30	68.492317	482.563578
7795	5	94.0	1.0	0.075325	22:12:45	44.069387	385.774107
7796	5	0.0	1.0	0.003893	22:13:00	2.474936	221.692133
7797	5	6.0	1.0	0.006534	22:13:15	4.012591	128.706828
7798	5	0.0	1.0	0.003435	22:13:30	2.208075	74.220209
7799	5	0.0	1.0	0.003716	22:13:45	2.372147	63.183453
7800	5	0.0	1.0	0.003637	22:14:00	2.326054	54.829289
7801	5	0.0	1.0	0.004128	22:14:15	2.611610	31.191735
7802	5	0.0	1.0	0.003439	22:14:30	2.210868	17.684373
7803	5	0.0	1.0	0.003159	22:14:45	2.047337	14.349980

In [14]:

```
# classify
test['Predicted wake'] = test.apply(lambda x: classify(x, 'Predicted Total Counts'), axis=1)

# set uninterrupted sleep values
test = __handle_missing_values(test, 'Predicted wake')

# print first 15 rows
test.head(15)
```

```
0 rows were dropped where both activity counts and classification were missing.
That is roughly 0.00% of the dataset.

268 classifications were set to 1 for the first and last 5 minutes of uninterrupted sleep.
That is roughly 3.21% of the dataset.
```

Out[14]:

	day	Actiwatch activity counts	Actiware classification	Apple Watch ENMO	time	Predicted activity counts	Predicted Total Counts	Predicted wake
7789	5	91.0	1.0	0.049485	22:11:15	29.023007	317.353564	1
7790	5	62.0	1.0	0.047339	22:11:30	27.773589	323.652867	1
7791	5	58.0	1.0	0.069403	22:11:45	40.621203	379.619787	1
7792	5	154.0	1.0	1.066049	22:12:00	620.965014	2585.415302	1
7793	5	164.0	1.0	0.503060	22:12:15	293.138021	1340.419208	1
7794	5	159.0	1.0	0.117267	22:12:30	68.492317	482.563578	1
7795	5	94.0	1.0	0.075325	22:12:45	44.069387	385.774107	1
7796	5	0.0	1.0	0.003893	22:13:00	2.474936	221.692133	1
7797	5	6.0	1.0	0.006534	22:13:15	4.012591	128.706828	1
7798	5	0.0	1.0	0.003435	22:13:30	2.208075	74.220209	1
7799	5	0.0	1.0	0.003716	22:13:45	2.372147	63.183453	1
7800	5	0.0	1.0	0.003637	22:14:00	2.326054	54.829289	1
7801	5	0.0	1.0	0.004128	22:14:15	2.611610	31.191735	1
7802	5	0.0	1.0	0.003439	22:14:30	2.210868	17.684373	1
7803	5	0.0	1.0	0.003159	22:14:45	2.047337	14.349980	1

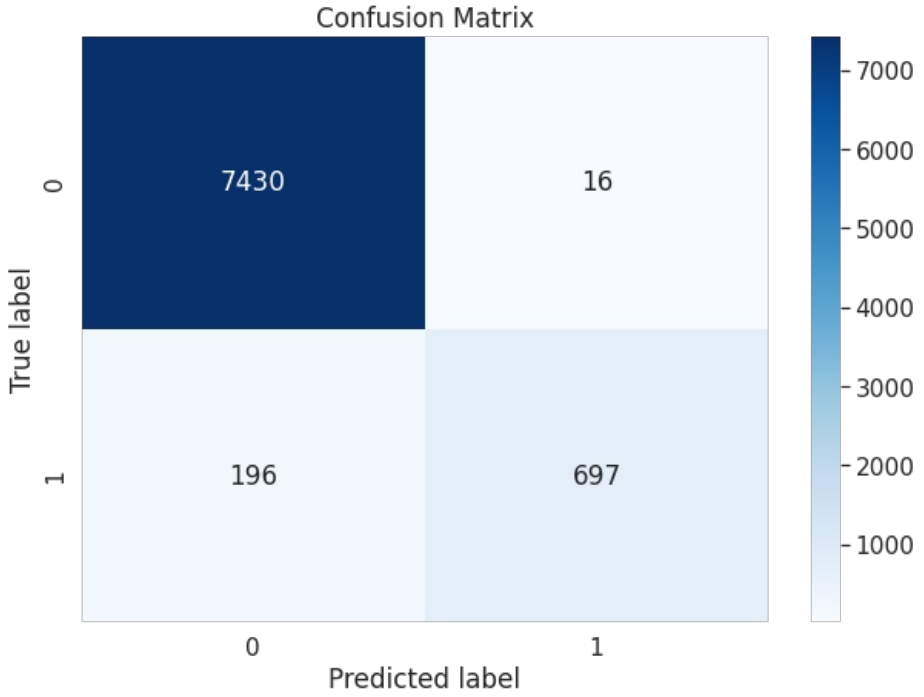
Print statistics of classification

Confusion matrix

In [15]:

```
# create matrix
conf_mat = confusion_matrix(test['Actiware classification'], test['Predicted wake'])

# put matrix into data frame
df_cm = pd.DataFrame(conf_mat, range(2), range(2))

# plot matrix with blues color style
plt.figure(figsize=(10,7))
```

```
sns.set(font_scale=1.4)

s = sns.heatmap(df_cm, annot=True, cmap='Blues', fmt='g')
s.set(xlabel='Predicted label', ylabel='True label', title='Confusion Matrix')

fig = s.get_figure()
fig.savefig("img/confusion_matrix.pdf", bbox='tight')
```



Metrics: Accuracy, Misclassification Rate, Precision, Recall, F1-score

Note: As we are trying to classify sleep, we consider 0 as the positive class

In [16]:

```
# Accuracy
acc = round(accuracy_score(test['Actiware classification'], test['Predicted wake'])*100, 2)
print("Accuracy score: \t", acc, '%')

# Misclassification Rate
print("Misclassification rate:\t", round(100-acc, 2), '%')

# Precision
print("Precision score:\t",
      round(precision_score(test['Actiware classification'], test['Predicted wake'], pos_label=0)*100, 2), '%')

# Recall
print("Recall: \t\t",
      round(recall_score(test['Actiware classification'], test['Predicted wake'], pos_label=0)*100, 2), '%')

# F1-Score
print("F1 score: \t\t",
      round(f1_score(test['Actiware classification'], test['Predicted wake'], pos_label=0)*100, 2), '%')
```

```
Accuracy score:          97.46 %
Misclassification rate:  2.54 %
Precision score:         97.43 %
Recall:                  99.79 %
F1 score:                98.59 %
```