Mobile Phone Lying still

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1 Mobile phone lying still on table

Importing libraries needed to run the rest of the notebook

[24]:
```
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
```

1.1 Read and check Data

Reading CSV files from Physics Toolbox Sensor Suite by Vieyra Software. There are some formatting issues with the files. Most importantly, the file is stored with an em-dash instead of hyphen. That I fixed manually before trying to import.

[25]:
```
filename = '2022-08-0719.04.25 phone lying still in living room.csv'
data = pd.read_csv(filename, delimiter=';',decimal=',',index_col=0)
```

1.1.1 Check files

Before moving on we should briefly check what we have imported.

[26]:
```
data
```

[26]:
```
                gFx     gFy     gFz       ax       ay       az       wx  \
time
0.037052     0,0000  0,0000  0.0000   0,0000   0,0000   0,0000   0,0858
0.097072     0,0000  0,0000  0.0000   0,0000   0,0000   0,0000  -0,0089
0.097695     0,0000  0,0000  0.0000  -6,7458   3,0130  -4,2359  -0,0089
0.148823     0,0000  0,0000  0.0000  -6,7458   3,0130  -4,2359   0,2569
0.149534     0,0000  0,0000  0.0000  -6,7754   2,9833  -4,2238   0,2569
…                …       …       …        …        …        …        …
535.752289  -0,1153  0,3017  0.9953  -0,1567   0,1217   0,4185   0,6016
535.752780  -0,1153  0,3017  0.9953  -0,1130   0,3235   0,3627   0,6016
535.800635  -0,0523  0,2763  0.9843  -0,1130   0,3235   0,3627   0,6016
535.801461  -0,0523  0,2763  0.9843  -0,1130   0,3235   0,3627   0,1343
535.801895  -0,0523  0,2763  0.9843   0,3719  -0,1411   0,3046   0,1343

                 wy       wz  Unnamed: 10
```

```
time
0.037052      0,0279  -0,0376          NaN
0.097072     -0,1871   0,0082          NaN
0.097695     -0,1871   0,0082          NaN
0.148823      0,0884  -0,0621          NaN
0.149534      0,0884  -0,0621          NaN
…              …       …       …
535.752289   -0,0891  -0,1528          NaN
535.752780   -0,0891  -0,1528          NaN
535.800635   -0,0891  -0,1528          NaN
535.801461   -0,2864  -0,0349          NaN
535.801895   -0,2864  -0,0349          NaN

[26788 rows x 10 columns]
```

There is one column too much, due to a semicolon at the end of the file. Therefore, we remove the extra column like this:

[27]:
```python
data = data.drop(data.columns[9],axis=1)
data
```

[27]:
```
                gFx     gFy     gFz       ax       ay       az       wx  \
time
0.037052     0,0000  0,0000  0.0000   0,0000   0,0000   0,0000   0,0858
0.097072     0,0000  0,0000  0.0000   0,0000   0,0000   0,0000  -0,0089
0.097695     0,0000  0,0000  0.0000  -6,7458   3,0130  -4,2359  -0,0089
0.148823     0,0000  0,0000  0.0000  -6,7458   3,0130  -4,2359   0,2569
0.149534     0,0000  0,0000  0.0000  -6,7754   2,9833  -4,2238   0,2569
…              …       …       …        …        …        …       …
535.752289  -0,1153  0,3017  0.9953  -0,1567   0,1217   0,4185   0,6016
535.752780  -0,1153  0,3017  0.9953  -0,1130   0,3235   0,3627   0,6016
535.800635  -0,0523  0,2763  0.9843  -0,1130   0,3235   0,3627   0,6016
535.801461  -0,0523  0,2763  0.9843  -0,1130   0,3235   0,3627   0,1343
535.801895  -0,0523  0,2763  0.9843   0,3719  -0,1411   0,3046   0,1343

                 wy       wz
time
0.037052      0,0279  -0,0376
0.097072     -0,1871   0,0082
0.097695     -0,1871   0,0082
0.148823      0,0884  -0,0621
0.149534      0,0884  -0,0621
…              …       …
535.752289   -0,0891  -0,1528
535.752780   -0,0891  -0,1528
535.800635   -0,0891  -0,1528
535.801461   -0,2864  -0,0349
```

```
535.801895  -0,2864  -0,0349

[26788 rows x 9 columns]
```

Let us just check what data types we have read in:

[28]:
```
data.dtypes
```

[28]:
```
gFx     object
gFy     object
gFz    float64
ax      object
ay      object
az      object
wx      object
wy      object
wz      object
dtype: object
```

There is obviously something wrong, since only one column has loaded with float values. By visual inspection we see that the minus signs are coded with a – (n-dash) instead of hyphen. This makes the importer fail, so that the decimal marker has not properly been changed from comma (,) to dot (.). So we need to change this.

[29]:
```
# Replacing n-dash with hyphen
data=data.replace(to_replace='–', value='-',regex=True)
# Replacing comma with dot
data=data.replace(to_replace=',', value='.',regex=True)
# Replacing comma with dot
data=data.replace(to_replace='ϖ', value='0',regex=True)
data
```

[29]:
```
                gFx     gFy     gFz      ax      ay      az      wx  \
time
0.037052     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000  0.0858
0.097072     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000 -0.0089
0.097695     0.0000  0.0000  0.0000 -6.7458  3.0130 -4.2359 -0.0089
0.148823     0.0000  0.0000  0.0000 -6.7458  3.0130 -4.2359  0.2569
0.149534     0.0000  0.0000  0.0000 -6.7754  2.9833 -4.2238  0.2569
…               …       …       …       …       …       …       …
535.752289  -0.1153  0.3017  0.9953 -0.1567  0.1217  0.4185  0.6016
535.752780  -0.1153  0.3017  0.9953 -0.1130  0.3235  0.3627  0.6016
535.800635  -0.0523  0.2763  0.9843 -0.1130  0.3235  0.3627  0.6016
535.801461  -0.0523  0.2763  0.9843 -0.1130  0.3235  0.3627  0.1343
535.801895  -0.0523  0.2763  0.9843  0.3719 -0.1411  0.3046  0.1343


                 wy      wz
time
```

```
0.037052      0.0279  -0.0376
0.097072     -0.1871   0.0082
0.097695     -0.1871   0.0082
0.148823      0.0884  -0.0621
0.149534      0.0884  -0.0621
…               …       …
535.752289  -0.0891  -0.1528
535.752780  -0.0891  -0.1528
535.800635  -0.0891  -0.1528
535.801461  -0.2864  -0.0349
535.801895  -0.2864  -0.0349

[26788 rows x 9 columns]
```

[30]:
```
# Now that the data should have been formatted correctly, we can change to␣
↪float64
data=data.astype(float)
data.dtypes
```

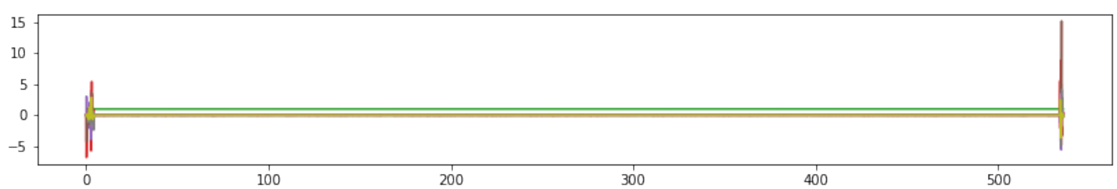
[30]:
```
gFx     float64
gFy     float64
gFz     float64
ax      float64
ay      float64
az      float64
wx      float64
wy      float64
wz      float64
dtype: object
```

1.1.2 Trim the data

I know that there is some extra motion in the beginning and end when I start and stop the recording. So we want to trim the data slightly. First, we need to check how much to trim.

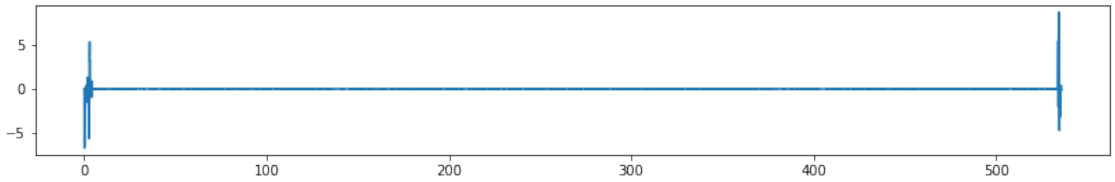
[31]:
```
# Plot the data to get an idea of the temporal development.

fig = plt.figure(figsize=(14,2))
plt.plot(data);
```



Since the data have different values, it is difficult to see exactly what is happening at the beginning and end. Let us therefore look at one of the the accelerometer values to investigate what goes on.

[32]:
```
fig = plt.figure(figsize=(14,2))
plt.plot(data.ax);
```



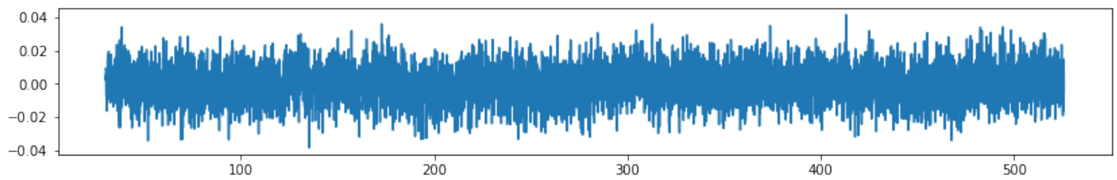
We can see that there is a lot of motion in the beginning and some in the end. So we want to remove those parts.

[33]:
```
# Removing samples from the beginning
data_without_beginning = data.tail(-1500)

#Removing samples from the end
data_clean = data_without_beginning.head(-500)
```

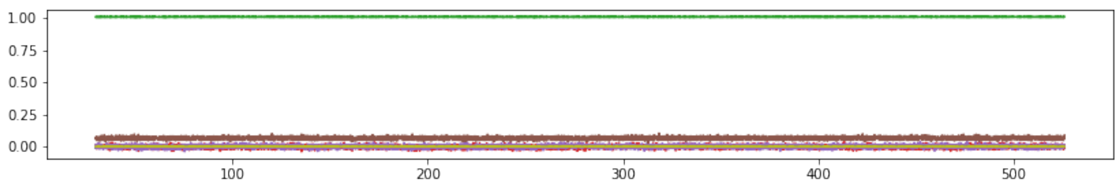
Checking that we managed to remove enough

[36]:
```
fig = plt.figure(figsize=(14,2))
plt.plot(data_clean.ax);
```



And then we can plot everything again.

[37]:
```
fig = plt.figure(figsize=(14,2))
plt.plot(data_clean);
```



Then we are ready to look at the content.

1.2 Analysis

Let us look some more at the data.

1.2.1 Descriptive statistics

[35]:
```
data.describe(include='all')
```

[35]:
```
                gFx           gFy           gFz            ax            ay  \
count  26788.000000  26788.000000  26788.000000  26788.000000  26788.000000
mean      -0.010713      0.009064      1.006844     -0.000886     -0.007342
std        0.022943      0.033667      0.024631      0.276606      0.182704
min       -0.578500     -0.448500      0.000000     -6.775400     -5.550300
25%       -0.011700      0.006100      1.006800     -0.007800     -0.005500
50%       -0.011000      0.006800      1.007300     -0.000900      0.001200
75%       -0.010300      0.007300      1.008000      0.006300      0.008000
max        0.768900      0.730500      2.207400      8.842300      3.013000

                 az            wx            wy            wz
count  26788.000000  26788.000000  26788.000000  26788.000000
mean       0.072392     -0.001120     -0.000234     -0.000249
std        0.216702      0.073987      0.139380      0.115436
min       -4.235900     -1.782600     -4.940600     -3.643300
25%        0.060900     -0.000700     -0.000500     -0.000500
50%        0.065800     -0.000100      0.000100      0.000000
75%        0.072900      0.000500      0.000200      0.000600
max       15.171200      3.409200      4.143600      2.846300
```

These are descriptions of the data and the units used:

Name	Description	Unit
gFx	g-force X	FN/Fg
gFy	g-force Y	FN/Fg
gFz	g-force Z	FN/Fg
ax	linear acceleration X	m/s2
ay	linear acceleration Y	m/s2
az	linear acceleration Z	m/s2
wx	gyroscope X	rad/s
wy	gyroscope Y	rad/s
wz	gyroscope Z	rad/s

The g-force and gyroscope are measured sensor values, while the “linear acceleration” is a combination of these sensors. Vieyra Software writes on the app web page about how it is calculated:

> Linear acceleration is derived from the g-force meter, but also uses the gyroscope and the magnetometer to negate the effects of the earth's gravitational field on the sensor.

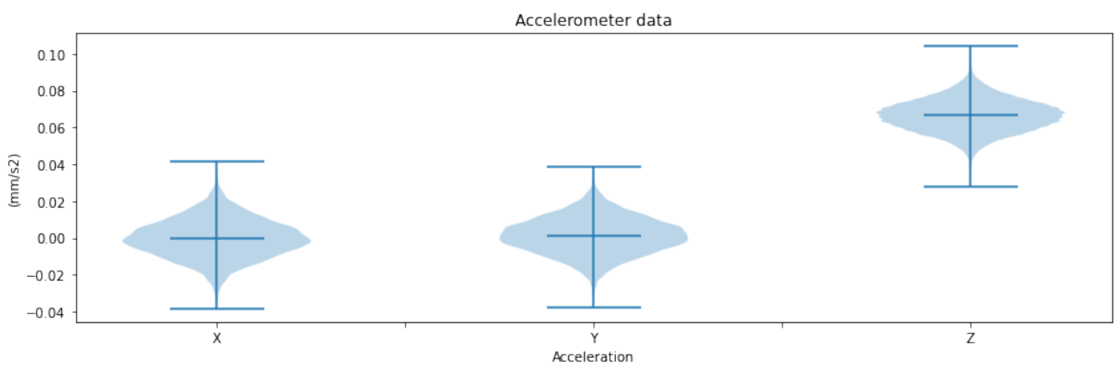
It is the linear acceleration that is most interesting in my case, so we can look at violin plots of the distribution of each axis:

[60]:
```
fig, ax = plt.subplots(figsize=(14,4))

ax.violinplot([data_clean['ax'],data_clean['ay'],data_clean['az']],␣
 ↪showmeans=True)
plt.title('Accelerometer data')
ax.set_xticklabels(["", "X", "", "Y", "", "Z"])
plt.xlabel('Acceleration');
plt.ylabel('(mm/s2)');

plt.show()
plt.savefig("accelerometer_violinplots.png", bbox_inches='tight')
```

```
/home/alexander/anaconda3/lib/python3.7/site-packages/ipykernel_launcher.py:5:
UserWarning: FixedFormatter should only be used together with FixedLocator
  """
```




```
<Figure size 432x288 with 0 Axes>
```

The distribution looks quite similar for each axis and the values are also very small.

1.2.2 Temporal development

Let us start by looking at the temporal development of data from the linear acceleration data.

[69]:
```
fig = plt.figure(figsize=(14,10))
aa1 = plt.subplot(3, 1, 1)
aa1.plot(data_clean['ax'], lw=1, label='X axis', color='red') #Displacement on␣
 ↪x axis
aa1.legend(loc='upper right')
```

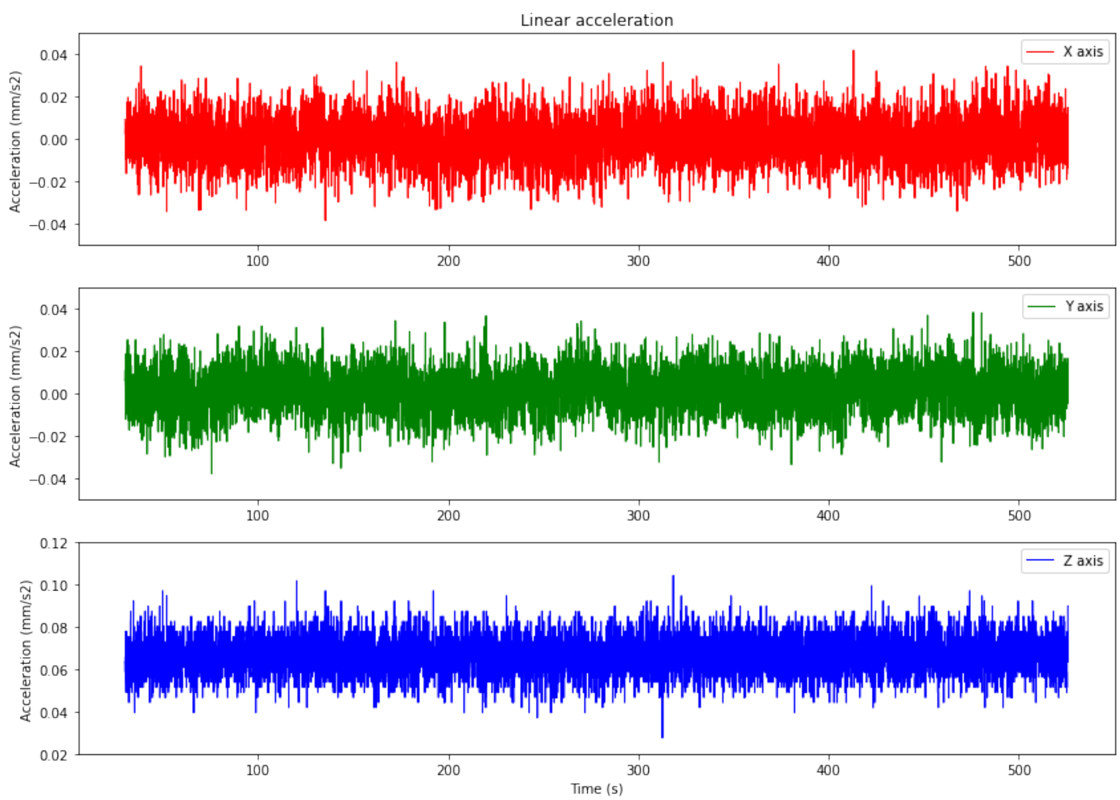
```
aa1.set_ylim(-0.05, 0.05)
plt.ylabel('Acceleration (mm/s2)');
plt.title('Linear acceleration')

aa2 = plt.subplot(3, 1, 2)
aa2.plot(data_clean['ay'], lw=1, label='Y axis', color='green') #Displacement␣
↪on x axis
aa2.set_ylim(-0.05, 0.05)
aa2.legend(loc='upper right')
plt.ylabel('Acceleration (mm/s2)');

aa3 = plt.subplot(3, 1, 3)
aa3.plot(data_clean['az'], lw=1, label='Z axis', color='blue') #Displacement on␣
↪x axis
aa3.set_ylim(0.02, 0.12)
aa3.legend(loc='upper right')
plt.ylabel('Acceleration (mm/s2)');

#plt.tick_params(axis='both', which='major')

plt.xlabel('Time (s)');
fig.savefig("accelerometer_time.png", bbox_inches='tight')
```



As expected, the data varies slightly over time, but the numbers are very small. Note that the X and Y data are centred around 0, while the Z data are slightly above 0. This may be due to lack of calibration. The app provides in-app calibration of the sensors, so I will try that for the next run.

We can also inspect the spatial distribution of the same sensor data.

1.2.3 Spatial trends

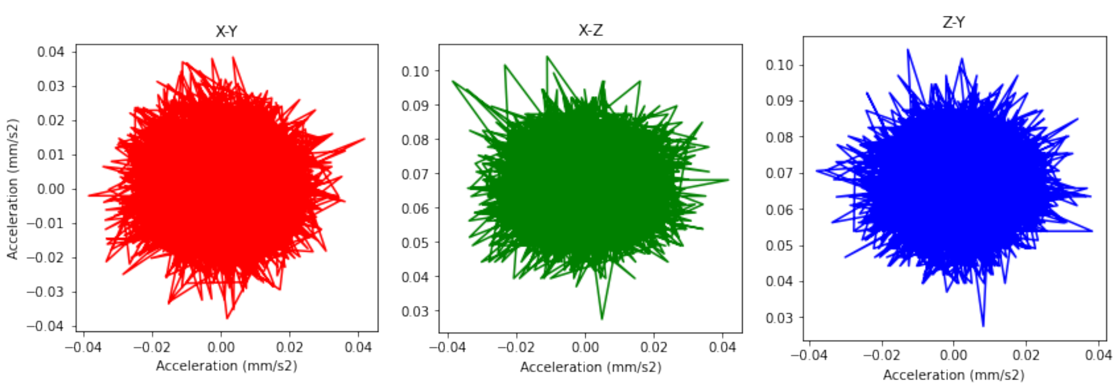
[70]:
```python
from matplotlib.ticker import FormatStrFormatter

fig = plt.figure(figsize=(14,6))
aa = plt.subplot(1, 3, 1)
plt.plot(data_clean['ax'], data_clean['ay'], color='r') #XY plane
plt.ylabel('Acceleration (mm/s2)');
plt.xlabel('Acceleration (mm/s2)');
plt.title('X-Y')
aa.set_aspect('equal')

ab = plt.subplot(1, 3, 2)
plt.plot(data_clean['ax'], data_clean['az'], color='g') #XZ plane
plt.xlabel('Acceleration (mm/s2)');
plt.title('X-Z')
ab.set_aspect('equal')

ac = plt.subplot(1, 3, 3)
plt.plot(data_clean['ay'], data_clean['az'], color='b') #ZY plane
plt.xlabel('Acceleration (mm/s2)');
plt.title('Z-Y')
ac.set_aspect('equal')

fig.savefig("accelerometer_planar.png", bbox_inches='tight')
```



Nothing special to report here either. The spatial distribution looks fine, with some spikes here and there.