Import relevant packages here.

In [15]:
```
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import math
```

Load the data and verify it is loaded correctly.

- Print it (head, tail, or specific rows, choose a sensible number of rows).
- Compare it to the source file.

In [8]:
```
data = pd.read_csv('cf_data.csv')
data.head()
```

Out[8]:

| | dv | s | a |
|---|---|---|---|
| **0** | -0.743240 | 53.5427 | 1.242570 |
| **1** | -0.557230 | 53.6120 | 1.777920 |
| **2** | -0.454769 | 53.6541 | 0.544107 |
| **3** | -0.525396 | 53.7030 | -0.294755 |
| **4** | -0.601285 | 53.7592 | -0.290961 |

In the ensuing, you will use `numpy`.

Let's create a grid for the values to plot. But first create **two arrays named `dv` and `s`** using `numpy.linspace` that hold the grid values at the relevant indices in their respective dimension of the grid.

Create a **grid named `a`** with zeros using `numpy.zeros` in to which calculated acceleration values can be stored.

Let the grid span:

- Speed difference `dv` [m/s]
  - From -10 till 10
  - With 41 evenly spaced values
- Headway `s` [m]
  - From 0 till 200
  - With 21 evenly spaced values

In [73]:
```
dv = np.linspace(-10, 10, 41)
s = np.linspace(0, 200, 21)
a = np.zeros((21, 41))
# print(a)
```

Create from the imported data 3 separate `numpy` arrays for each column `dv`, `s` and `a`. (We do this for speed reasons later.)

- Make sure to name them differently from the arrays that belong to the grid as above.
- You can access the data of each column in a `DataFrame` using `data.xxx` where `xxx` is the column name (not as a string).
- Use the method `to_numpy()` to convert a column to a `numpy` array.

In [63]:
```
DV = data.dv.to_numpy()
S = data.s.to_numpy()
A = data.a.to_numpy()
```

Create an algorithm that calculates all the acceleration values and stores them in the grid. The algorithm is described visually in the last part of the lecture. At each grid point, it calculates a weighted mean of all measurements. The weights are given by an exponential function, based on the 'distance' between the grid point, and the measurement values of `dv` and `s`. To get you started, how many `for`-loops do you need?

For this you will need `math`.
Use an *upsilon* of 1.5m/s and a *sigma* of 30m.

**Warning:** This calculation may take some time. So:

- Print a line for each iteration of the outer-most `for`-loop that shows you the progress.
- Test you code by running it only on the first 50 measurements of the data.

In [69]:
```
upsilon = 1.5
sigma = 30

# DV_50 = data.dv.to_numpy()[:50]
# S_50 = data.s.to_numpy()[:50]
# A_50 = data.a.to_numpy()[:50]

for i in range(len(dv)):
    print(f'now we are calculating the {i+1}/41 dv gridpoint..')

    for j in range(len(s)):
        sum_weight = 0
        total_weight = 0

        for k in range(len(DV)):
            weight_dv = math.exp(-abs((dv[i] - DV[k])) / upsilon)
            weight_s = math.exp(-abs((s[j] - S[k])) / sigma)
            weight = weight_dv * weight_s

            sum_weight += weight * A[k]
            total_weight += weight

        a[j, i] = sum_weight / total_weight
```

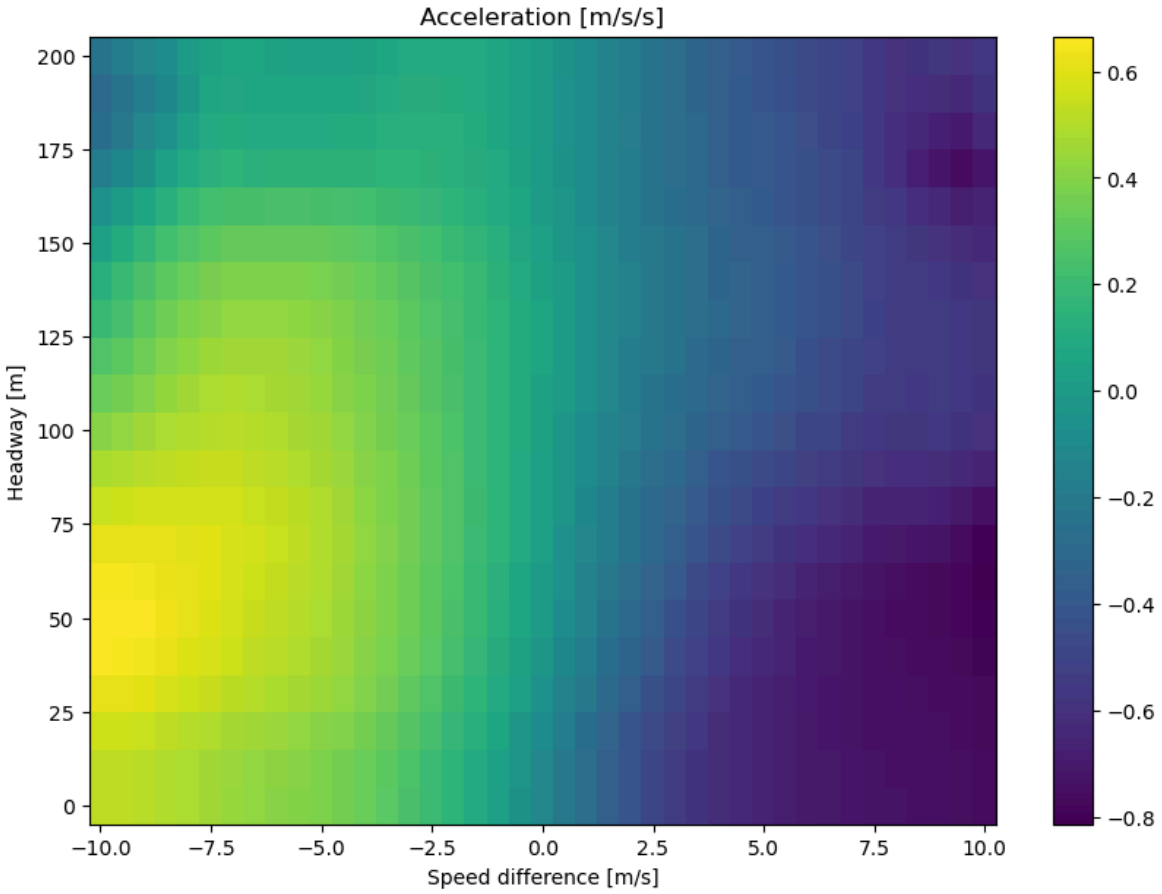
```
now we are calculating the 1/41 dv gridpoint..
now we are calculating the 2/41 dv gridpoint..
now we are calculating the 3/41 dv gridpoint..
now we are calculating the 4/41 dv gridpoint..
now we are calculating the 5/41 dv gridpoint..
now we are calculating the 6/41 dv gridpoint..
now we are calculating the 7/41 dv gridpoint..
now we are calculating the 8/41 dv gridpoint..
now we are calculating the 9/41 dv gridpoint..
now we are calculating the 10/41 dv gridpoint..
now we are calculating the 11/41 dv gridpoint..
now we are calculating the 12/41 dv gridpoint..
now we are calculating the 13/41 dv gridpoint..
now we are calculating the 14/41 dv gridpoint..
now we are calculating the 15/41 dv gridpoint..
now we are calculating the 16/41 dv gridpoint..
now we are calculating the 17/41 dv gridpoint..
now we are calculating the 18/41 dv gridpoint..
now we are calculating the 19/41 dv gridpoint..
now we are calculating the 20/41 dv gridpoint..
now we are calculating the 21/41 dv gridpoint..
now we are calculating the 22/41 dv gridpoint..
now we are calculating the 23/41 dv gridpoint..
now we are calculating the 24/41 dv gridpoint..
now we are calculating the 25/41 dv gridpoint..
now we are calculating the 26/41 dv gridpoint..
now we are calculating the 27/41 dv gridpoint..
now we are calculating the 28/41 dv gridpoint..
now we are calculating the 29/41 dv gridpoint..
now we are calculating the 30/41 dv gridpoint..
now we are calculating the 31/41 dv gridpoint..
now we are calculating the 32/41 dv gridpoint..
now we are calculating the 33/41 dv gridpoint..
now we are calculating the 34/41 dv gridpoint..
now we are calculating the 35/41 dv gridpoint..
now we are calculating the 36/41 dv gridpoint..
now we are calculating the 37/41 dv gridpoint..
now we are calculating the 38/41 dv gridpoint..
now we are calculating the 39/41 dv gridpoint..
now we are calculating the 40/41 dv gridpoint..
now we are calculating the 41/41 dv gridpoint..
```

In [72]:
```
# print(a)
```

The following code will plot the data for you. Does it make sense when considering:

- Negative (slower than leader) and positive (faster than leader) speed differences?
- Small and large headways?

In [71]:
```
X, Y = np.meshgrid(dv, s)
axs = plt.axes()
p = axs.pcolor(X, Y, a, shading='nearest')
axs.set_title('Acceleration [m/s/s]')
axs.set_xlabel('Speed difference [m/s]')
axs.set_ylabel('Headway [m]')
axs.figure.colorbar(p);
axs.figure.set_size_inches(10, 7)
```


Acceleration [m/s/s]
Headway [m]
Speed difference [m/s]
200
175
150
125
100
75
50
25
0
−10.0
−7.5
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8

In [ ]:

In [ ]:

In [ ]: