

MULTIVARIABLE CALCULUS

MATH S-21A

Data illustration 2: Acceleration data

2.1. There are apps on your cellphone that can measure your acceleration data. Using these data, we can construct the curve $\vec{r}(t) = [x(t), y(t), z(t)]$ which describes the path which we have taken with the phone. What the data provide are lists of numbers which encode the **acceleration data** $x''(t), y''(t), z''(t)$. Summing up these data and fixing the initial velocities give lists of numbers which encode the **velocity data** $x'(t), y'(t), z'(t)$. Now one can do it again and get the **position data**.

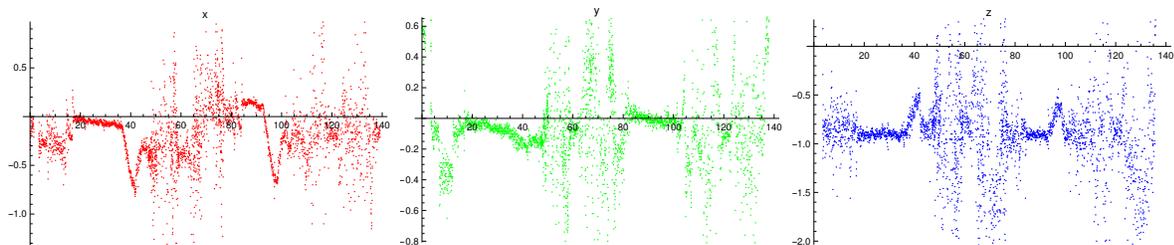
2.2. In the blog

<http://blog.robindeits.com/2013/11/11/roller-coaster-visualizations>,

Robin Deits has used a smartphone to measure the accelerations during a **roller coaster ride** on **Cedar point**, the foremost American roller coaster park.

Robin made the data available on the website <https://github.com/rdeits/coasters>.

2.3. Here are the **x-acceleration**, the **y-acceleration** and the **z-acceleration** data, plotted in a particular case, the Mine ride roller coaster:



2.4. One can get back the actual shape of the roller coaster from these data:



Image source: <https://coasterforce.com/mine-train>

2.5. Here are the 20 example data points. The first column is time, the second column is the x-acceleration, the third the y-acceleration and the fourth the z-acceleration.

```
A={
{ 0.002, -0.29, 0.59, 0.90},
{ 0.078, -0.26, 0.55, 0.85},
{ 0.080, -0.34, 0.67, 0.88},
{ 0.147, -0.22, 0.59, 0.88},
{ 0.192, -0.16, 0.55, 0.80},
{ 0.255, -0.15, 0.57, 0.85},
{ 0.257, -0.18, 0.57, 0.84},
{ 0.347, -0.18, 0.59, 0.72},
{ 0.383, -0.05, 0.58, 0.91},
{ 0.446, -0.13, 0.72, 0.81},
{ 0.485, -0.12, 0.63, 0.81},
{ 0.510, -0.01, 0.58, 0.93},
{ 0.581, -0.04, 0.53, 0.86},
{ 0.637, -0.01, 0.38, 0.93},
{ 0.684, -0.07, 0.54, 0.86},
{ 0.700, -0.15, 0.50, 0.79},
{ 0.777, -0.16, 0.57, 0.98},
{ 0.827, -0.12, 0.55, 0.98},
{ 0.902, -0.11, 0.56, 0.97},
{ 0.904, -0.05, 0.57, 0.97}}
};
```

Problem 1: How would you use this list of data to get a list of data representing the velocities assuming that the velocities at $t = 0$ are zero.

Problem 2: How would you use the velocity data to get the position data assuming that at $t = 0$ we have the position $(0, 0, 0)$.

Problem 3: On the data page, you have access to a Mathematica program and data files from that curve. Describe what the programs are doing.

Problem 4: Plot both graphs, the original curve and the reconstructed curve.

Problem 5: Explain why the two curves are translated to each other.

Acknowledgment: Original idea for the project Summer 2019: Jun-Hou Fung.

OLIVER KNILL, KNILL@MATH.HARVARD.EDU, MATH S-21A, HARVARD SUMMER SCHOOL, 2021