Motion 3 - Tracking

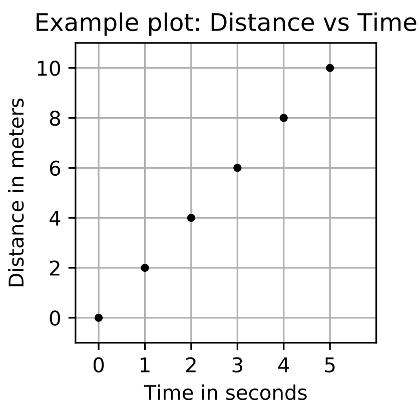
You have been throwing things since your first tantrum as a child. In fact, we are so good at throwing that it has been suggested as one of the main differences between humans and other primates, `https://www.nature.com/articles/nature12267`.

It is only natural then that your first analysis of motion is throwing a ball. Mythbuster's analyzed motion of objects by recording them with a camera and playing the video back frame-by-frame. You too will have that power!

Notes - copy into your labbook

Calculating Velocity and Acceleration from Time and Distance

Velocity and acceleration are BOTH calculated from a table of time vs distance.



Time (s)	**Distance** (m)	**Velocity** (m/s)	**Acceleration** (m/s^2)
0	0	-	-
1	2		-
2	4		
3	6		
4	8		
5	10		

Velocity is the slope of distance and time, NOT simply distance divided by time.

$$\text{Velocity} = \frac{\text{Change in Distance}}{\text{Change in time}} = \frac{\text{(Current distance) - (Previous distance)}}{\text{(Current time) - (Previous time)}}$$

Acceleration is the slope of velocity and time, NOT simply the velocity divided by time.

$$\text{Accleration} = \frac{\text{Change in Velocity}}{\text{Change in time}} = \frac{\text{(Current velocity) - (Previous velocity)}}{\text{(Current time) - (Previous time)}}$$

Example

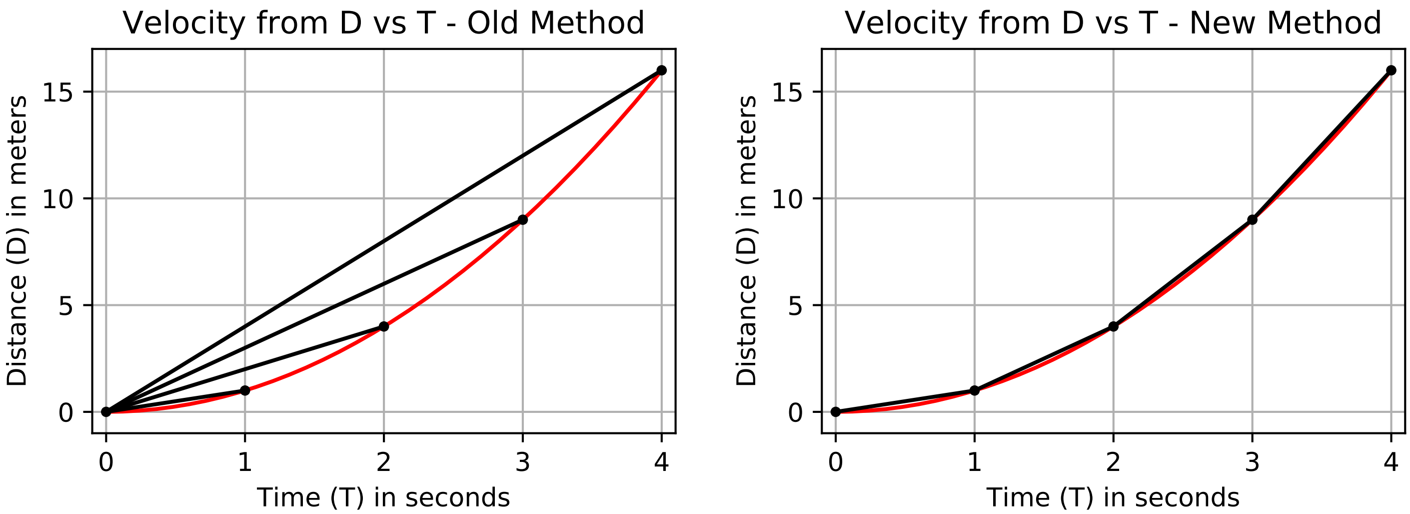
Time	**Distance**	**Velocity**	**Acceleration**
0s	0m	-	-
1s	2m	$\frac{2m-0m}{1s-0s} = \frac{2m}{1s} = 2\,\text{m/s}$	-
2s	4m	$\frac{4m-2m}{2s-1s} = \frac{2m}{1s} = 2\,\text{m/s}$	$\frac{2\,\text{m/s}-2\,\text{m/s}}{2s-1s} = \frac{0\,\text{m/s}}{1s} = 0\,\text{m/s}^2$

Instructions for notes - (you need to fill out the table)

Previously you have been taught that, $Velocity = \frac{Distance}{Time}$. You are now mature enough to learn the more correct, $Velocity = \frac{Change\ in\ Distance}{Change\ in\ Time}$.

Change in means that you look at where you are at and where you just were, the difference is change in. In the old definition everything was referenced from the start where as now everything is referenced to the last point.

The difference is shown below:



Note how the old method each velocity calculation goes back to the origin, where as in the new method each calculation uses adjacent points.

You are learning all of this so you can understand what the tracker program is doing. This method of calculating velocity and acceleration is how your car calculates speed, how your GPS/phone calculate speed, and everything around you. It is not nearly as complicated as you would expect! All you need is a series of pictures!

Instructions for notes continues on the next page.

Instructions for notes - continued

What follows is a more detailed version of the example table you copied into your notes. To calculate velocity at 1s:

$$\text{Velocity at 1 second} = \frac{\text{Change in Distance}}{\text{Change in Time}} = \frac{(\text{Position at 1 second}) - (\text{Position at 0 seconds})}{(\text{Time at 1 second}) - (\text{Time at 0 seconds})}$$

$$V(1) = \frac{P(1) - P(0)}{T(1) - T(0)} = \frac{2m - 0m}{1s - 0s} = \frac{2m}{1s} = 2\,\mathrm{m/s}$$

$V(1)$ is called function notation. $V(1)$ means that V, velocity, at time 1 second.

To calculate velocity when time is 2 seconds:

$$\text{Velocity at 2 seconds} = \frac{\text{Change in Distance}}{\text{Change in Time}} = \frac{(\text{Position at 2 seconds}) - (\text{Position at 1 second})}{(\text{Time at 2 seconds}) - (\text{Time at 1 second})}$$

$$V(2) = \frac{P(2) - P(1)}{T(2) - T(1)} = \frac{4m - 2m}{2s - 1s} = \frac{2m}{1s} = 2\,\mathrm{m/s}$$

Now fill out the rest of the velocities.

Note, we cannot calculate the first velocity since we don't have a distance for -1 second.

What follows is a more detailed version of what is in the example table that you copied into your notes. To calculate acceleration at 2s:

$$\text{Acceleration} = \frac{\text{Change in Velocity}}{\text{Change in Time}} = \frac{(\text{Velocity at 2 seconds}) - (\text{Velocity at 1 second})}{(\text{Time at 2 seconds}) - (\text{Time at 1 second})}$$

$$A(2) = \frac{2\,\mathrm{m/s} - 2\,\mathrm{m/s}}{2s - 1s} = \frac{0\,\mathrm{m/s}}{1s} = 0\,\mathrm{m/s^2}$$

Now fill out the rest of the accelerations. Note, we cannot calculate the acceleration for the 0s and 1s because you need two consecutive velocities to calculate the change in velocity

Things to note:

- The velocity is the slope of the distance graph.
- The acceleration is the slope of the velocity graph.
- The acceleration is zero if the velocity doesn't change.

Activity

You will record yourself throwing a ball then analyze the video using 'Tracker'. The goal is to gain a familiarity with the 'Tracker' application so you can complete the next couple activities.

Setup - Procedure

- Record a video of a person throwing a ball underhand in an arc.
  - Make sure the ball is visible in the whole video
  - Try to NOT move the camera
  - Have the meter stick in the background for calibration
- Get a flash drive with the 'Tracker' program on it.
- Open the 'Tracker' application from the 'Tracker' folder on the flashdrive.

Questions for Labbook

Sketch the following 7 plots into your labbook. The purpose of the graphs is to get you thinking about how position (x & y), velocity (vx & vy), and acceleration (ax & ay) are inter-related.

X-axis vs **Y-axis**
x vs y
t vs x
t vs y
t vs vx (velocity-x)
t vs vy (velocity-y)
t vs ax (acceleration-x)
t vs ay (acceleration-y)

Notes on sketching

- Always label your axis, both with the description and the unit. I recommend 'Description (unit)'.
- Always indicate where zero is on both axis.
- Tick marks are NOT needed, however you should mark the high and low, or average value so people can place where the sketch is on the graph.
- All that is important is the shape of the graph, not the individual values.