What is Velocity?

So What is Velocity? Why should I care? Why do I need motion blur? Why is my effect moving weird? Why Why Why Why Why Why Why Why ……WHY.

It's velocity. That's why.

- Velocity, on a more serious note is super important. Not just from a CGI standpoint, but from a physics one.

- Velocity is calculated in a vector quantity, and is defined as something as: "the rate at which an object changes its position."

- But an object that moves very quickly and maintains the same position, will have zero velocity. Imagine yourself grooving out on the dance floor and flailing your arms around. Sorta like your awkward uncle who never learned how to dance. Well, as fast as your arms might be moving, you are resulting in zero velocity. THis is because you are returning to your original position, which overall does not result in a change in position.

- The terms of velocity describe how fast or slowly an object moves. Or how it's position varies with time. It is also defined as the formula: r = d/t

- r = rate (often also denoted as v, symbolizing velocity)
- d = distance the object moved
- t = time the object took

There are several different types of velocity…..So let's cover them.

- **Uniform Velocity**
- **Variable Velocity**
- **Average Velocity**
- **Instantaneous Velocity**

Uniform velocity is the easiest to calculate. For example, let's picture a particle in 3D space. Imagine that particle traveling through and towards different points in space with the same speed.

- In this situation, the product of the particle's velocity "v" and the time interval "t" yields the particle's displacement "s" over a given time interval "t."

- The formula of Uniform Velocity is ⇒ Displacement = Velocity x Time Interval.

- Or s= vt.

- Non-Uniform Velocity is also called Variable Velocity. The easiest way to describe it is to picture a point moving around a circle. At each point in the circle, the curve, and other variables forcing it around that route, will affect the points path in a constant way.

- In summary, its speed and direction is dependent on a certain variable(s).

Average velocity is the total displacement calculated when the entire period of velocity is calculated.

You can calculate it with this equation:

- Displacement (a vector pointing from your initial position to your final position) / Total Time = Average Velocity.

Instantaneous Velocity describes how fast an object moves at different intervals. The magnitude of the velocity is equal to the current speed of the object. The magnitude of the instantaneous velocity equals the instantaneous speed.

You can calculate it with this equation:

- v(t) = d/dt (x (t))

- Instantaneous velocity is a vector having a length per time dimension, just like average velocity.

Initial and Final Velocity are two different things. **Initial velocity** is how fast an object travels when gravity exerts a force on it. **Final velocity** is a vector quantity that showcases an object's direction and speed after it has reached its maximum acceleration.

You can calculate **Initial Velocity** with this formula:

Since the Initial Velocity(vi) is the velocity before the object changes due to acceleration, you can calculate it by using these factors:

- vi = Initial Velocity (in m/s)
- vf = Final Velocity (in m/s)
- a = acceleration (in m/s2)
- t = time taken by the object (in s)

Vi = vf - a x t

Calculating the **Final Velocity** is a bit different:

- The final speed of an object is equal to its starting velocity, plus acceleration. Multiplied by the time that it has traveled.

$v = u + a\Delta t$

- v = final velocity
- u = initial velocity
- a = acceleration
- Δt = time difference

Constant velocity is described as an object having a linear path of motion at certain intervals of time.

This means the speed of the object has not changed even though the direction of the object has. Constant velocity is motion with zero acceleration.

$x = x0 + vt$

- x0 = displacement at time t,
- v = constant velocity of the body

What is the difference between Velocity and Speed?

- Speed is a scalar quantity, and does not keep track of the direction of the object.
- Velocity is a vector quantity and is direction aware.

How Do You Determine the Direction of Velocity?

- The direction of a velocity vector is the same direction that the object is moving in. Even if the object is slowing down, or changing speeds, this does not change the direction.

<u>So let's talk about speed.</u>

Let's start with calculating **Average Speed**.

As an object moves, it undergoes a change in speed. Speed will always change overtime, and is rarely constant. The average speed can be thought of as the average of all readings of how the speed changed over intervals of time.

Average Speed vs Instantaneous Speed - Not The Same

Instantaneous Speed - the speed at any given instant in time.
Average Speed - the average of all instantaneous speeds.

But Why is Velocity a Vector?

When you are defining velocity. You need to calculate both the magnitude and direction of it. The scalar absolute value of velocity is speed. Which is the magnitude. (Usually measured in m/s or m-s-1)

The direction is where things get tricky. For example:

- If you say: something is moving 5 meters per second. - **This is scalar**.
- If you say: This object is moving 5 meters per second East. - **This is a vector**.

The directional information is what defines it as a vector. Scalar quantities are measurements that are more often used for temperature, your weight, or the population of a country. These are scalars because they are completely defined by a single number.

- Velocity has both magnitude and direction that is why it is a vector quantity.
- Speed has only magnitude and no direction that is why it is a scalar quantity.

Motion Blur and Velocity

“Reduce motion blur by 30%, otherwise I’m not looking at it”. - The VFX Producer

<u>What is motion blur, and why is it so important?</u>

- Motion blur in a CGI sense is how we can simulate speed. Or rather visually see it.

- But photography wise, motion blur is the apparent streaking of moving objects in a photograph or a sequence of frames. It results when the image being recorded changes during the recording of a single exposure, due to rapid movement or long exposure.

- In a video game sense, motion blur helps smooth out a game's appearance, and increases realism.

- Motion blur needs velocity to work. If the object is not in motion, or in motion and no velocity information, motion blur will not appear.

In Houdini, Mantra supports **three types of motion blur**. Each depends on the type of animated geometry you want to blur.

- Transform motion Blur

- Deformation motion blur
- Velocity motion blur

Transform motion Blur simulates blur by calculating the object's transformations between frames.

- This is the default setting for motion blur in Houdini. However, it does not blur deformations. Deformations are from the object changing shape over time.

Deformation motion blur simulates blur by re-cooking an object's geometry and transformations between frames.

- This blur type is very heavy, so optimization is key. It also allows you to change the blur over shutter time.

- Deformation motion blur can't handle changing point/primitive numbers because it can't know which components from one sample correspond to which components in the next sample.

Velocity motion blur simulates blur by interpolating point positions based around velocity(v), acceleration(a), and angular velocity(w).

- This blur type is used when an object's point number changes over time.This is the only blur type that can do this. For example, fluid simulations.

In mantra, you need to turn on **Allow Motion Blur** on the **Rendering Tab**, otherwise nothing will work. When you turn this on, **Xform time samples, Geo time samples, and Shutter offset** will appear.

- **Geo Time Samples** are the number of subframes Mantra needs to compute when rendering deformation motion blur. The default is 1. Which adds no deformation motion blur.

The Motion Factor parameter is on **the Dicing tab**.

- Fast moving objects that need lots of motion blur are rendered with the same sampling quality as any other object. However, sometimes motion blur takes away detail from your final render.

- This happens quite frequently in fast moving objects. If this is the case, you might want to consider using the motion factor parameter.

- Increasing this parameter will reduce the shading quality of the object based on its motion. Which helps a lot with objects that have displacement based shading, and move very quickly.

- The motion factor will be dependent on the degree of motion in the scene.

You might be wondering why there are geometry motion blur settings on your object nodes.

Well there are a few reasons!

The Geometry Motion Blur settings have two options you can set it to:

- Velocity
- Acceleration

The velocity setting will keep your velocity handling on Houdini's default settings

The acceleration setting will handle objects that have different speeds of movement, and if they deform over time.

Also keep in mind the motion of the camera in your scene will also affect your motion blur. It can also have its own custom sampling rates, which may distort your image.

Things to Remember

- Velocity of a body is the rate at which an object's position changes with a frame of reference and time.
- Velocity is considered as a function of displacement, while speed is a function of distance that is traveled.
- To define velocity, we need both magnitude and direction.
- Instantaneous velocity is the speed at any given time, whereas average velocity is the total displacement divided by total time.
- Acceleration is indicated by a changing velocity.
- The variation between speed and velocity is that speed informs us how rapidly an object is going, but velocity tells us not only how fast an object is moving but also in which direction it is traveling. ..
- The average velocity is calculated by multiplying the total displacement by the entire time, v = xt, where x is the total displacement of the body and t is the time.
- Average speed is always less than or equal to average velocity; this is because displacement can never exceed the distance traveled, yet the distance traveled can exceed displacement.

Units of Velocity

- The SI unit for velocity is m/s or ms-1.

Units of Velocity
SI Unit: m/s
Other Units: ft/s, mph
Common Symbol: r, v, v

Velocity Fields

What is a velocity field?

- A velocity field is distributed velocity within a given region. For example, let's say you have a box. Every point inside that box has a velocity vector. This is a velocity field.

- It also means that the velocity inside this region is denoted in a functional form. Which is V(x,y,z,t) . This means velocity is a function of spatial and time coordinates. This also means the direction and magnitude of the velocity is scattered through the field as well.

- In physics terms, when you are looking for the velocity field of a flow, the flow speed is scalar. The length of the flow velocity vector is also the flow speed.

A 2D velocity field can be described a bit differently.

- The easiest way to explain a 2D velocity field is to use a Houdini example. In Houdini, on most of the DOP networks and solvers, there are visualization options. Particularly for visualizing forces such as turbulence, noise, disturbance, etc. With these visualizers, you can visualize the flow of the field.

- A velocity field (or 2D flow field) describes fluid flow using a vector field. Streamlines are plotted for the velocity field generated by the components of the velocity vector. The streamlines are tangent to the velocity field everywhere.

Is there velocity in Magnetic fields?

- Yes!

- The magnetic field always exerts a force perpendicular to the particle's velocity, so the magnitude of the velocity remains constant. Therefore, the kinetic energy remains constant.

- It is not possible to change the velocity of a particle in a magnetic field as the magnetic field does not work like charged particles.

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