"just like the simulations"

What comes to mind?

If I say the word **Simulation**, what do you think of?
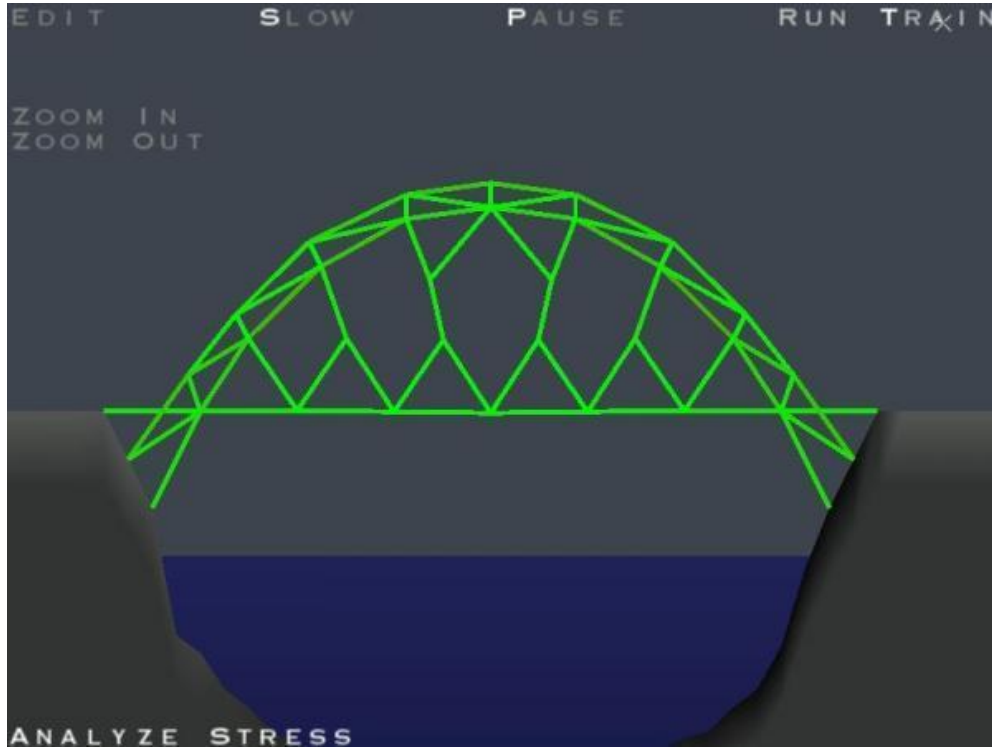
Simulations

A **Simulation** is a program that is designed to *simulate* <small>omg wow who would've guessed</small> a real life scenario!

Simulations are useful because they allow us to mimic real-world events without risking real-world costs or dangers. They also allow us to see potential outcomes of various scenarios, and tweak inputs to see different outcomes!
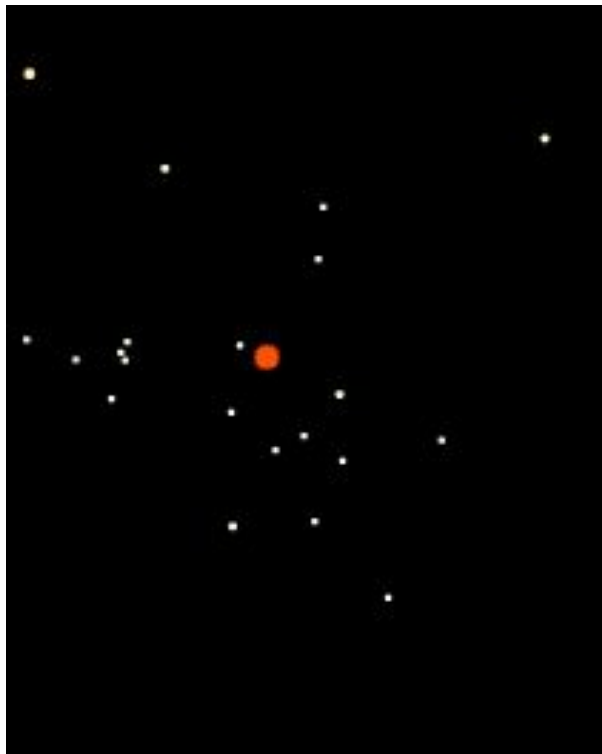
Example Simulations - Bridge Building

Example Simulations - Flight

Example Simulations - Gravity

Simulations

All **simulations** are built based on a *model* of how the world works.

A model is simply the set of rules for how things are going to interact in the simulation.

Since there are so many different factors at play in the world around us, having a simplified model can make creating a simulation much easier.
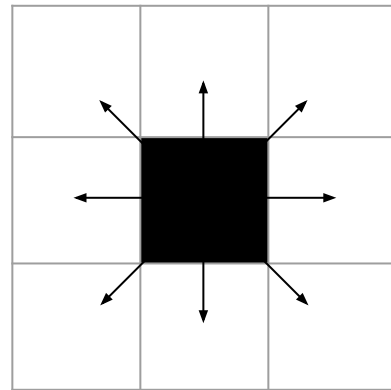
Example: Game of Life

One famous simulation is **Conway's Game of Life**. It simulates cell-like beings living and dying based on a set of rules, outlined in its model.
Here's what the model looks like:

- Each cell is either **alive** or **dead**
  - If a cell is **alive**, its square will show up as black. If **dead**, its square will be white.
- Start with a random number of living cells
- On each iteration of the simulation:
  - If a cell has fewer than 2 living neighbors, it dies
  - If a cell has 2 living neighbors, it stays the same
  - If a cell has 3 living neighbors, it comes to life
  - If a cell has 4 or more living neighbors, it dies

Example: Game of Life

This simulation is fairly simplistic, but it gives a good idea of how simulations work in general.

We could also potentially extend this simulation and make its model more complex to see how populations might grow or shrink as a result of things like genetics or disease!

Complex vs Simple Models

The simpler the model, the faster the simulation will run.

As a model gets increasingly complex, it requires more and more computing power to generate the simulation!

This is why it's difficult to simulate the world exactly as it is, and why we use a model to simplify various factors!

Complex vs Simple Models

Usually models simplify the world in order to only focus on the important thing that needs to be simulated.

We can ignore gravity, ignore air resistance, or only have 2 dimensions instead of 3, depending on what you are simulating! The possibilities are endless!

A Simple Gravity Simulation

Model:

- There is 1 ball in the simulation.
  - The ball has an x velocity and a y velocity.
- At each moment in the simulation:
  - Add 5 to the y velocity
  - If the ball is hitting a wall:
    - Reverse the velocity of the ball

A Complex Gravity Simulation

Model:

- There are various celestial objects in the simulation
  - Each one has a different mass and velocity
- At each moment in the simulation:
  - Every particle in the simulation is pulled toward every other particle according to the formula:

$$F = \frac{G\,M\,m}{r^2}$$

F = force of gravity
G = gravitational constant
(6.67 x 10^{-11})
M = mass of one object
m = mass of other object
r = distance between the two objects

Simulation Application

Simulations are often used to predict things about the world around us.

We can create a model, use real information about the world, and then simulate it thousands of times to find out what is most likely to happen!

Predicting Sports Standings

TEAM	DIVISION	RATING	1-WEEK CHANGE	AVG. SIMULATED SEASON		POSTSEASON CHANCES		
				RECORD	RUN DIFF.	MAKE PLAYOFFS	WIN DIVISION	WIN WORLD SERIES
C **Cubs** 87-47	NL CENTRAL	1583	+4	104-58	+256	>99%	>99%	27%
🔵 **Blue Jays** 76-57	AL EAST	1554	+7	92-70	+116	91%	61%	11%
W **Nationals** 78-55	NL EAST	1544	-1	95-67	+164	>99%	99%	7%
B **Red Sox** 74-59	AL EAST	1543	-2	90-72	+132	76%	32%	9%
🌟 **Astros** 71-62	AL WEST	1538	+4	86-76	+54	28%	2%	2%

Training AI to play Games

We can simulate thousands of games of chess to help an AI figure out what moves tend to be the best!

Benefits of Simulations

Simulations allow us to form and test our hypotheses about how the world works.

Using simulations, we can test and improve our hypotheses easily, and we can constantly improve the simulation with rapid testing and tweaking!