Simulation and Animation II
Announcements

- Guest Lecture Thursday **during regular class time**
  - Please mark your calendars and attend!
Announcements

- Guest Lecture Thursday **during regular class time**
  - Inigo Quillez
Announcements

- Guest Lecture Thursday **during regular class time**
  - Inigo Quillez
Announcements

- Guest Lecture Thursday **during regular class time**
  - Joshua Moreno
Announcements

- Guest Lecture Thursday **during regular class time**
  - Joshua Moreno
Homework 4

Asef Islam and Dilan Nana

Michael Nixon
Virtual Time

Frame 1 + Frame 2 + Frame 3 + Frame 4

= Envato Tuts Animation tutorial

Frame 1
Simulation

F = -9.81
V = 0
P = .04

A = -9.81
V_next = -.39
P_next = .024

Frame 1

F = -9.81 + momentum
V = -.78
P = .024

A = -9.81
V_next = -.78
P_next = .007

Frame 2

F = -9.81
V = -.78
P = 0

A = N/A
V_next = +.78
P_next = .031

Frame 3

F = -9.81
V = .78
P = .031

A = -9.81
V_next = +.39
P_next = .04

Frame 4

Envato Tuts Animation tutorial
Simulation

old velocity = (0, 0) meters/second
old position = (0, .04) meters

Mass = 1.0 g

Force = (0, -9.81 * mass)N
time step = .04 seconds

acceleration = \frac{\text{force}}{\text{mass}}

change in Velocity = acceleration * time step

New velocity = old velocity + change in velocity

change in position = new velocity * time step

New position = Old Position + change in position
Simulation

old velocity = (0, 0) meters/second
old position = (0, .04) meters
Mass = 1.0 g

Force = (0, -9.81 * mass)N
time step = .04 seconds

acceleration = force / mass
acceleration = (0, -9.81 * 1.0g) N / 1.0g
acceleration = (0, -9.81) m/s^2

change in Velocity = acceleration * time step
change in Velocity = (0, -9.81)m/s^2 * .04s
change in Velocity = (0, -.39)m/s

New velocity = old velocity + change in velocity
New velocity = (0,0)m/s + (0, -.39)m/s
New velocity = (0, -.39)m/s

change in position = new velocity * time step
change in position = (0, -.39)m/s * .04s
change in position = (0, -.016)m

New position = Old Position + change in position
New position = (0, .04) m + (0, -.016)m
New position = (0, .024)m
Simulation

old velocity = (0, 0) meters/second
old position = (0, 0.04) meters
Mass = 1.0 g

Force = (0, -9.81 * mass)N
time step = 0.04 seconds

acceleration = \frac{\text{force}}{\text{mass}} = \frac{(0, -9.81 \times 1.0 \text{g}) \text{N}}{1.0 \text{g}} = (0, -9.81) \text{m/s}^2

change in Velocity = \text{acceleration} \times \text{time step} = (0, -9.81) \text{m/s}^2 \times 0.04 \text{s}
change in Velocity = (0, -0.39) \text{m/s}

New velocity = \text{old velocity} + \text{change in velocity} = (0, 0) \text{m/s} + (0, -0.39) \text{m/s}
New velocity = (0, -0.39) \text{m/s}

change in position = \text{new velocity} \times \text{time step} = (0, -0.39) \text{m/s} \times 0.04 \text{s}
change in position = (0, -0.016) \text{m}

New position = \text{Old Position} + \text{change in position} = (0, 0.04) \text{m} + (0, -0.016) \text{m}
New position = (0, 0.024) \text{m}
Simulation

Frame 1:
\[ F = -9.81 \]
\[ V = 0 \]
\[ P = .04 \]
\[ A = -9.81 \]
\[ V_{\text{next}} = -.39 \]
\[ P_{\text{next}} = .024 \]

Frame 2:
\[ F = -9.81 \]
\[ V = -.39 \]
\[ P = .024 \]
\[ A = -9.81 \]
\[ V_{\text{next}} = -.78 \]
\[ P_{\text{next}} = -.007 \]

Frame 3:
\[ F = -9.81 \]
\[ V = -.78 \]
\[ P = 0 \]
\[ A = N/A \]
\[ V_{\text{next}} = +.78 \]
\[ P_{\text{next}} = .031 \]

Frame 4:
\[ F = -9.81 \]
\[ V = .78 \]
\[ P = .031 \]
\[ A = -9.81 \]
\[ V_{\text{next}} = .39 \]
\[ P_{\text{next}} = .04 \]
Gravity simulation
Simulation

old velocity = (0, 0) meters/second
old position = (0, .04) meters

Mass = 1.0 g

Force = (5.0, 0) N

time step = .04 seconds

acceleration = \frac{force}{mass}
acceleration = \frac{(5.0, 0) N}{1.0 g}
acceleration = (5.0, 0) \text{ m/s}^2

change in Velocity = acceleration \times time step
change in Velocity = (5.0, 0) \text{ m/s}^2 \times .04s
change in Velocity = (.2, 0) \text{ m/s}

New velocity = old velocity + change in velocity
New velocity = (0,0) \text{ m/s} + (.2, 0) \text{ m/s}
New velocity = (.2, 0) \text{ m/s}

change in position = new velocity \times time step
change in position = (.2, 0) \text{ m/s} \times .04s
change in position = (.008, 0) \text{ m}

New position = Old Position + change in position
New position = (0, .04) \text{ m} + (.008, 0) \text{ m}
New position = (.008, .04) \text{ m}
Attraction Simulation
Attraction Simulation
Multiple Forces

**Force** = (5.0, 0) N

**Force** = (0, -9.81 * mass) N

**Mass** = 1.0 g

**old velocity** = (0, 0) meters/second

**old position** = (0, .04) meters

**change in Velocity** = **acceleration** * time step

**change in Velocity** = (5.0, -9.81 m/s^2) * .04 s

**change in Velocity** = (.2, -.39) m/s

**New velocity** = **old velocity** + change in velocity

**New velocity** = (0, 0) m/s + (.2, -.39) m/s

**New velocity** = (.2, -.39) m/s

**change in position** = **new velocity** * time step

**change in position** = (.2, 0) m/s * .04 s

**change in position** = (.008, -.016) m

**New position** = Old Position + change in position

**New position** = (0, .04) m + (.008, -.016) m

**New position** = (.008, .024) m
Multiple Forces
Simulation

\[
\text{acceleration} = \frac{\text{force}}{\text{mass}}
\]

\[
\text{change in Velocity} = \text{acceleration} \times \text{time step}
\]

\[
\text{New velocity} = \text{old velocity} + \text{change in velocity}
\]

\[
\text{change in position} = \text{new velocity} \times \text{time step}
\]

\[
\text{New position} = \text{Old Position} + \text{change in position}
\]
Questions?
Simulation
Simulation
Simulation

Esteban Diacono
Artistry in Simulation
Artistry in Simulation

Purvi Goel, Unified Many-Worlds Browsing of Arbitrary Physics-based Animations, SIGGRAPH
Artistry in Simulation

The Shining, 1980

Ready Player One, 2018
Artistry in Simulation

Spiderman: Into the Spiderverse, 2018
Artistry in Simulation

Elemental, 2023
Questions?
Simulation
Simulation

COLD

HOT
What do birds do?

- Birds like to follow each other
- Birds don’t want to be too close to each other
- When flying, birds look for spaces with low air resistance
- Every little bit, birds need a rest
- If birds see food, they will probably go eat it
Flocking Simulation

- Birds like to follow each other
- Birds don’t want to be too close to each other
  - When flying, birds look for spaces with low air resistance
  - Every little bit, birds need a rest
  - If birds see food, they will probably go eat it
Flocking Simulation

- Birds like to follow each other
- Birds don’t want to be too close to each other
- When flying, birds look for spaces with low air resistance
- Every little bit, birds need a rest
- If birds see food, they will probably go eat it
Flocking Simulation

- Fish like to follow each other
- Fish don’t want to be too close to each other
- Fish like to swim with fish of the same species
What about people?

- Zombies can only walk on a surface, or climb on a surface with over 30% elevation
- Zombies aren’t very good at climbing
- When zombies fall, they take a minute, then get back up and keep going
- Zombies want to get to the other side of the wall
What about people?

- Zombies can only walk on a surface, or climb on a surface with over 30% elevation

- Zombies aren’t very good at climbing

- When zombies fall, they take a minute, then get back up and keep going

- Zombies want to get to the other side of the wall
What about people?

- People can only walk on surfaces
- Often people have a destination in mind
- People don’t want to be too close to strangers
Questions?
Human Animation
Human Animation
Human Animation
Animation Cycles
Animation Cycles
Animation Cycles
Animation Cycles
Animation Cycles
Character Animation
Rigging and Inverse Kinematics

Forward Kinematics (FK)
Joint Angles $q_1, q_2, q_3, q_4$

Inverse Kinematics (IK)
End Effector Pose $x, y, \theta$

End Effector $(x, y)$
Rigging and Inverse Kinematics

Forward Kinematics

Inverse Kinematics
Meshes and IK bones
Character Animation
Questions?
Virtual Time

Frame 1 + Frame 2 + Frame 3 + Frame 4 = Envato Tuts Animation tutorial
Hand Drawn Animation
Animation Spline
Animation Spline
Animation Spline
Animation Spline
Questions?