

Game Physics



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Game Programming, Fall 2020 @ National Taiwan University

Game Programming

- Rendering
- Looping and control
- Math
- Animation
- Physics
- Behaviour and navigation (AI)
- Effects
- Networking

Game Programming

- Rendering
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Physics

- Simulation
 - Rigidbody dynamics
 - Forces
 - Mass
 - Gravity
 - Friction

Physics

- Simulation
 - Rigidbody dynamics
 - Collision detection



Unity physics engines

- Built-in 2D physics engine
- Built-in 3D physics engine
- DOTS physics engine




Unity physics engines

- Built-in 2D physics engine
 - Box2D: <https://github.com/erincatto/box2d>
- Built-in 3D physics engine
 - Nvidia PhysX
- DOTS physics engine
 - Unity Physics / Havok Physics for Unity




Rigidbody

▼  Rigidbody ? ≡ ⋮

| | |
|---------------------|-------------------------------------|
| Mass | 1 |
| Drag | 0 |
| Angular Drag | 0.05 |
| Use Gravity | <input type="checkbox"/> |
| Is Kinematic | <input checked="" type="checkbox"/> |
| Interpolate | Interpolate ▼ |
| Collision Detection | Discrete ▼ |
| ▶ Constraints | |
| ▶ Info | |



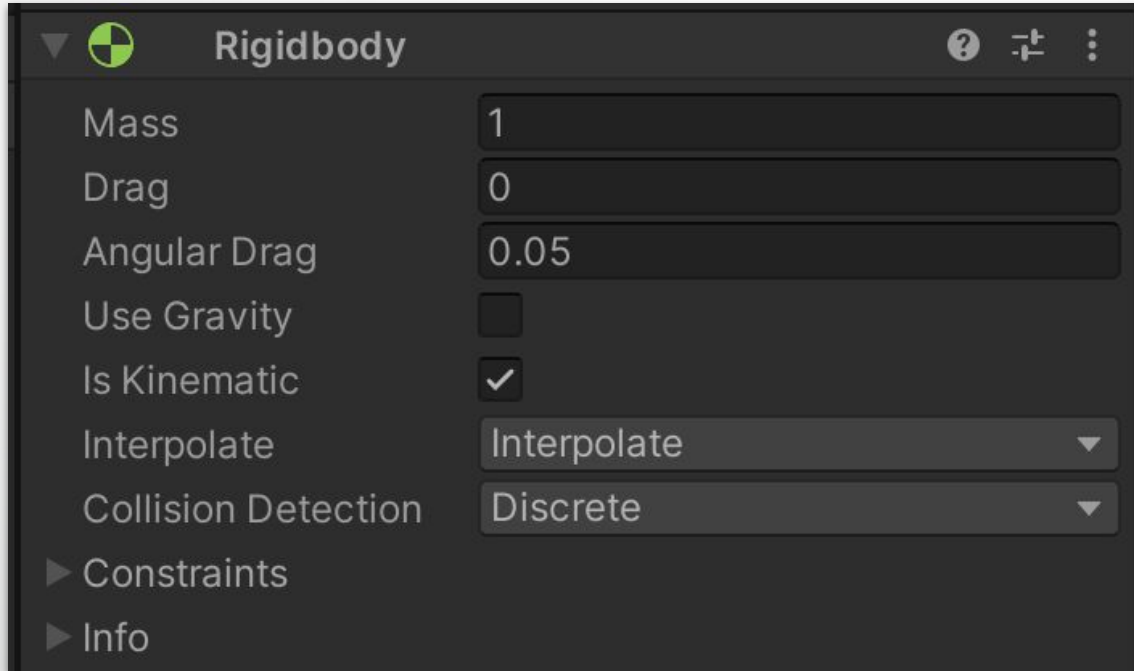
Rigidbody

 **Rigidbody** ? ≡ ⋮

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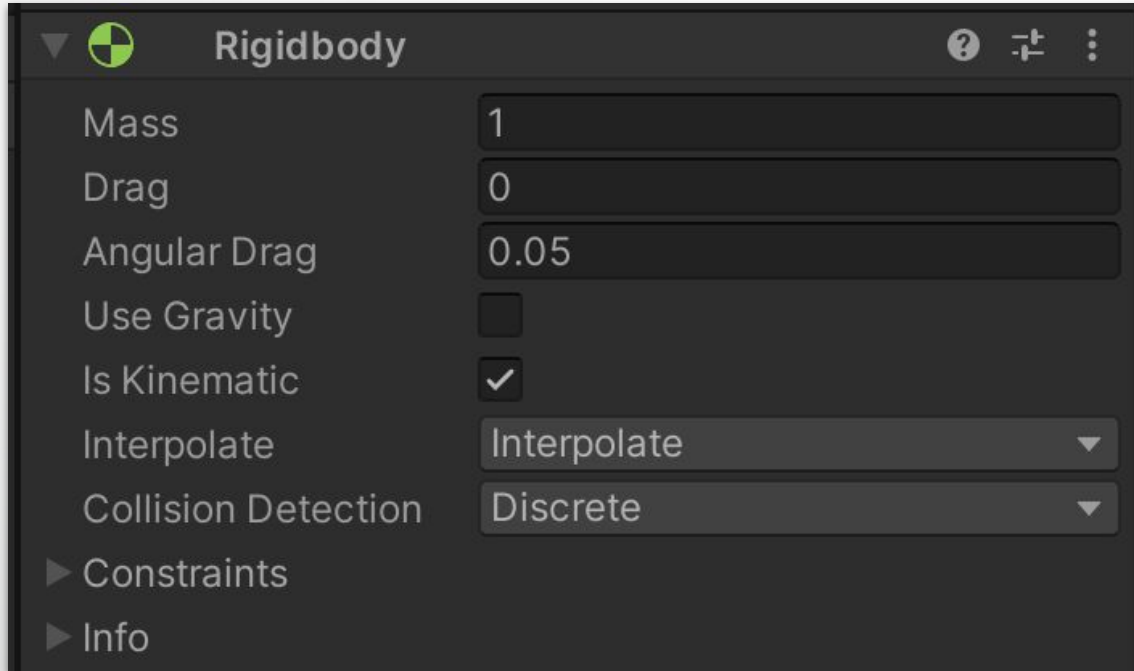
Rigidbody



Character controller ?



Rigidbody



Character controller ?

Non-player : Rigidbody



Project settings: Physics

Project Settings

Physics

| | | | |
|------------------------------------|-------------------------------------|---------|-----|
| Gravity | X 0 | Y -9.81 | Z 0 |
| Default Material | None (Physic Material) | | |
| Bounce Threshold | 2 | | |
| Sleep Threshold | 0.005 | | |
| Default Contact Offset | 0.01 | | |
| Default Solver Iterations | 6 | | |
| Default Solver Velocity Iterations | 1 | | |
| Queries Hit Backfaces | <input type="checkbox"/> | | |
| Queries Hit Triggers | <input checked="" type="checkbox"/> | | |
| Enable Adaptive Force | <input type="checkbox"/> | | |
| Contacts Generation | Persistent Contact Manifold | | |
| Auto Simulation | <input checked="" type="checkbox"/> | | |
| Auto Sync Transforms | <input checked="" type="checkbox"/> | | |
| Reuse Collision Callbacks | <input type="checkbox"/> | | |
| Cloth Gravity | X 0 | Y -9.81 | Z 0 |
| Contact Pairs Mode | Default Contact Pairs | | |



Demo : 3D Game Kit

- Create a new **Scene**
- Add an **Cube** with Rigidbody component
 - isKinematic
 - useGravity



Project settings: Time

Project Settings

Audio
Editor
Graphics
Input Manager
Package Manager
Physics
Physics 2D
Player
Preset Manager
Quality
Script Execution Order
Tags and Layers
▼ TextMesh Pro
 Settings
Time
VFX
XR Plugin Management

Time

Fixed Timestep: 0.02

Maximum Allowed Timestep: 0.3333333

Time Scale: 1

Maximum Particle Timestep: 0.03

?

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Demo : 3D Game Kit

- Create a new **Scene**
- Change **FixedUpdateTimestep**
- Add a **Cube** and let it fall



Rigidbody

▼  Rigidbody ? ≡ ⋮

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| Collision Detection | Discrete ▼ |

▶ Constraints

▶ Info



Demo : 3D Game Kit

- Create a new **Scene**
- Change **FixedUpdateTimestep**
- Add a **Cube** and let it fall

Collision detection

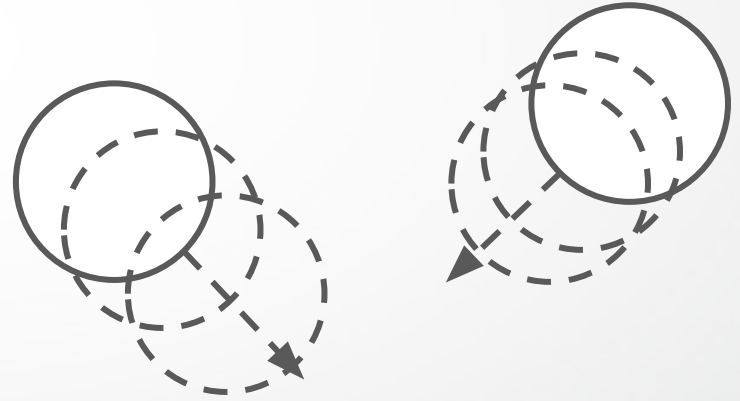
- Performance
 - Discrete collision detection
 - Continuous collision detection

Discrete collision detection

- Intersection test
 - Point-circle
 - Point-rectangle
 - Circle-circle
 - Circle-rectangle
 - Point-stadium
 - ...

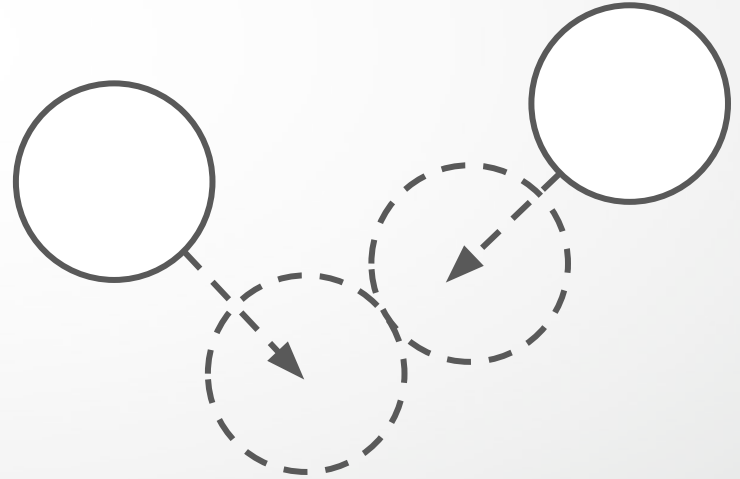
Discrete collision detection

- Intersection test
- Temporal search
 - FixedUpdate() ?



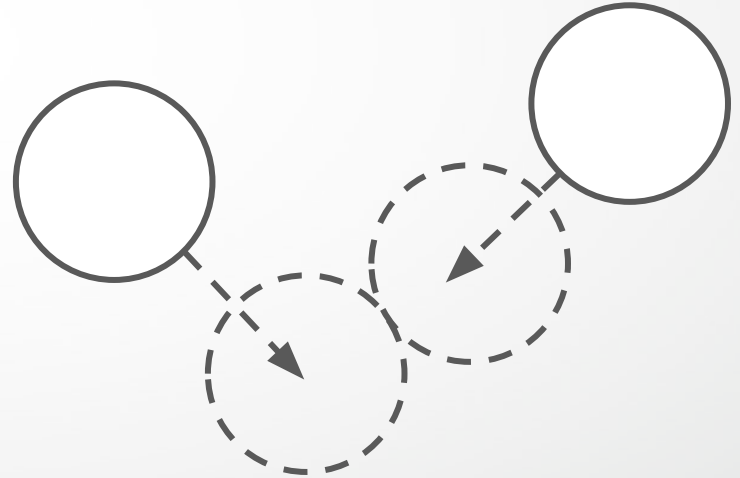
Discrete collision detection

- Intersection test
- Temporal search
 - Accurate result ?



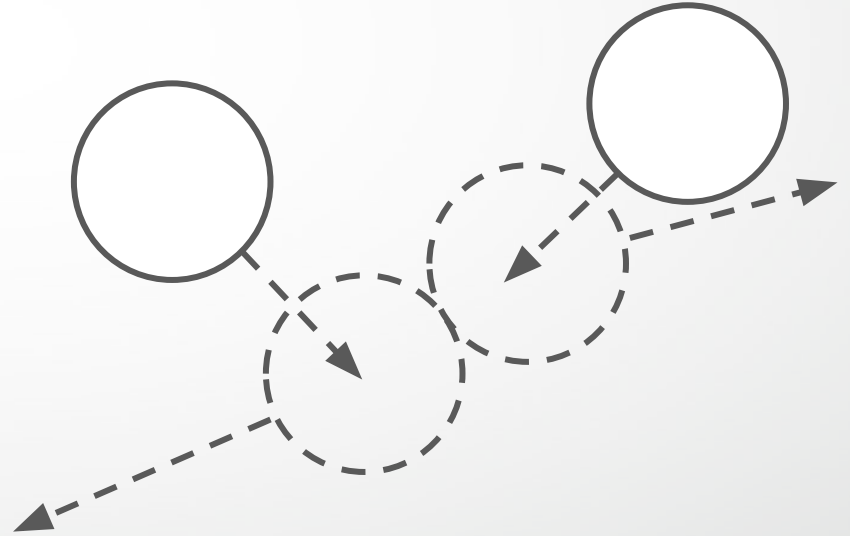
Discrete collision detection

- Intersection test
- Temporal search
 - Accurate result ?
 - Linear / binary search ?



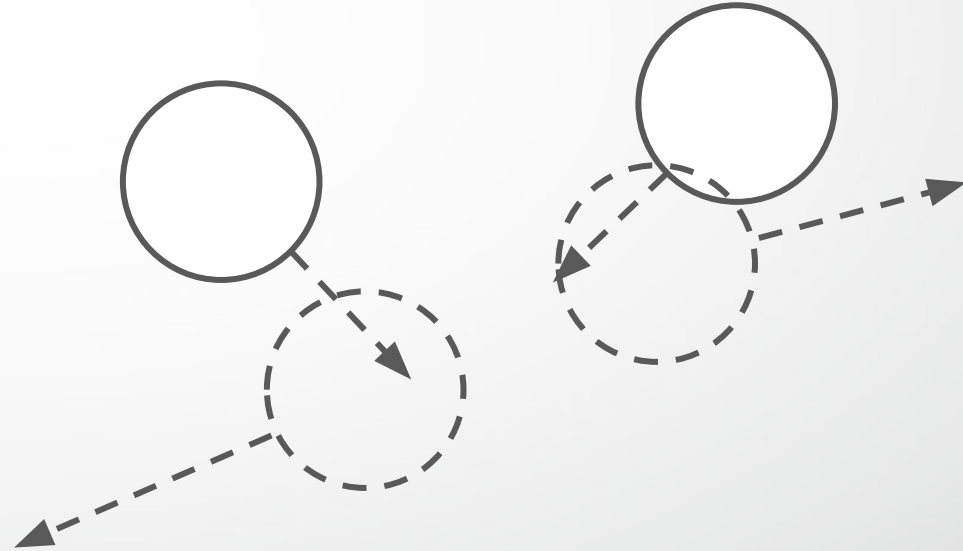
Discrete collision detection

- Intersection test
- Temporal search
 - Accurate result ?
 - Linear / binary search ?
 - Final result ?



Discrete collision detection

- Intersection test
- Temporal search
 - Accurate result ?
 - Linear / binary search ?
 - Final result ?





Colliders

- The shape of a GameObject for the purposes of physical collisions :
 - box collider, sphere collider, capsule collider, ...



Colliders

- The shape of a GameObject for the purposes of physical collisions :
 - box collider, sphere collider, capsule collider, ...
 - compound, or mesh collider ?



Colliders

- The shape of a GameObject for the purposes of physical collisions :
 - box collider, sphere collider, capsule collider, ...
 - compound, or mesh collider ?
 - convex



Colliders

- The shape of a GameObject for the purposes of physical collisions :
 - box collider, sphere collider, capsule collider, ...
 - compound, or mesh collider ?
 - convex
 - Trigger
 - without real collisions



Collider interactions

- Static Collider
 - static
- Rigidbody Collider
 - collide with each other
- Kinematic Rigidbody Collider
 - ... static ?

Collision detection occurs and messages are sent upon collision

| | Static Collider | Rigidbody Collider | Kinematic Rigidbody Collider | Static Trigger Collider | Rigidbody Trigger Collider | Kinematic Rigidbody Trigger Collider |
|--------------------------------------|-----------------|--------------------|------------------------------|-------------------------|----------------------------|--------------------------------------|
| Static Collider | | Y | | | | |
| Rigidbody Collider | Y | Y | Y | | | |
| Kinematic Rigidbody Collider | | Y | | | | |
| Static Trigger Collider | | | | | | |
| Rigidbody Trigger Collider | | | | | | |
| Kinematic Rigidbody Trigger Collider | | | | | | |

Trigger messages are sent upon collision

| | Static Collider | Rigidbody Collider | Kinematic Rigidbody Collider | Static Trigger Collider | Rigidbody Trigger Collider | Kinematic Rigidbody Trigger Collider |
|--------------------------------------|-----------------|--------------------|------------------------------|-------------------------|----------------------------|--------------------------------------|
| Static Collider | | | | | Y | Y |
| Rigidbody Collider | | | | Y | Y | Y |
| Kinematic Rigidbody Collider | | | | Y | Y | Y |
| Static Trigger Collider | | Y | Y | | Y | Y |
| Rigidbody Trigger Collider | Y | Y | Y | Y | Y | Y |
| Kinematic Rigidbody Trigger Collider | Y | Y | Y | Y | Y | Y |

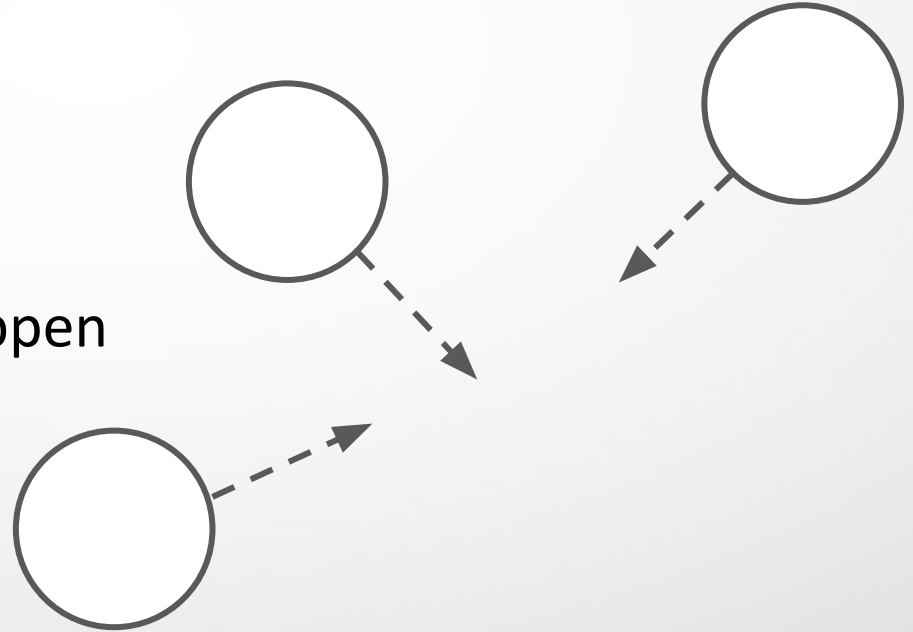


Demo : 3D Game Kit

- Create a new **Scene**
- Add two **Cube** and make them collide

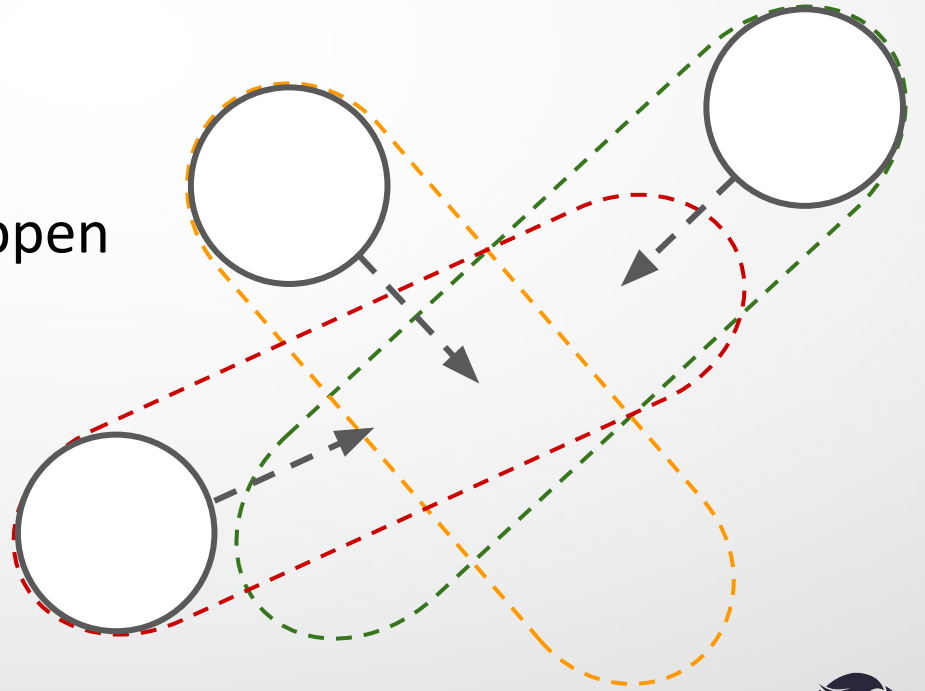
Discrete collision detection

- Intersection test
- Temporal search
 - Fast objects ?
- Multiple collisions may happen



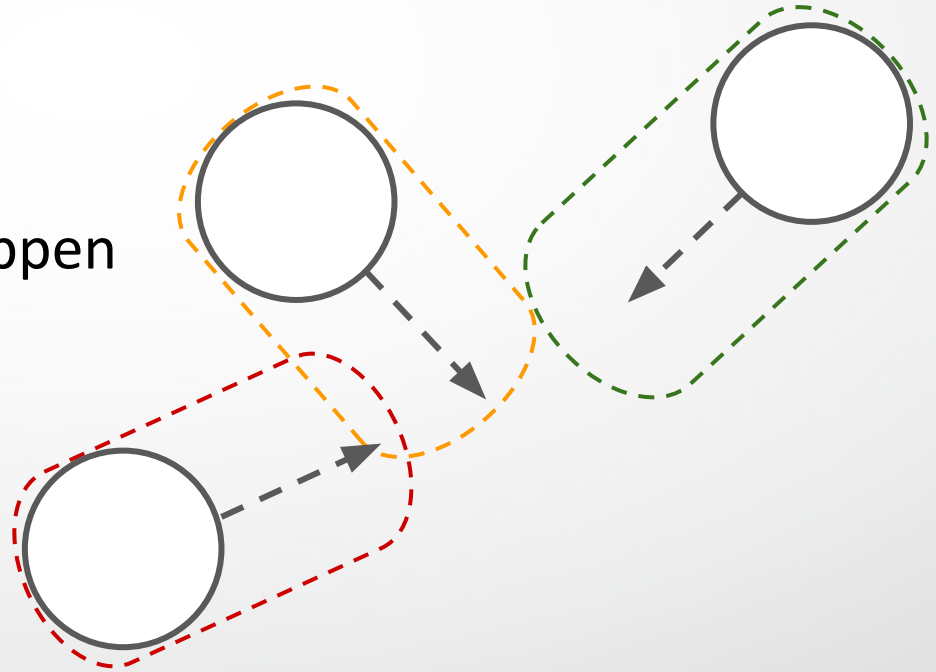
Continuous collision detection

- Intersection test
- Temporal search
- Multiple collisions may happen



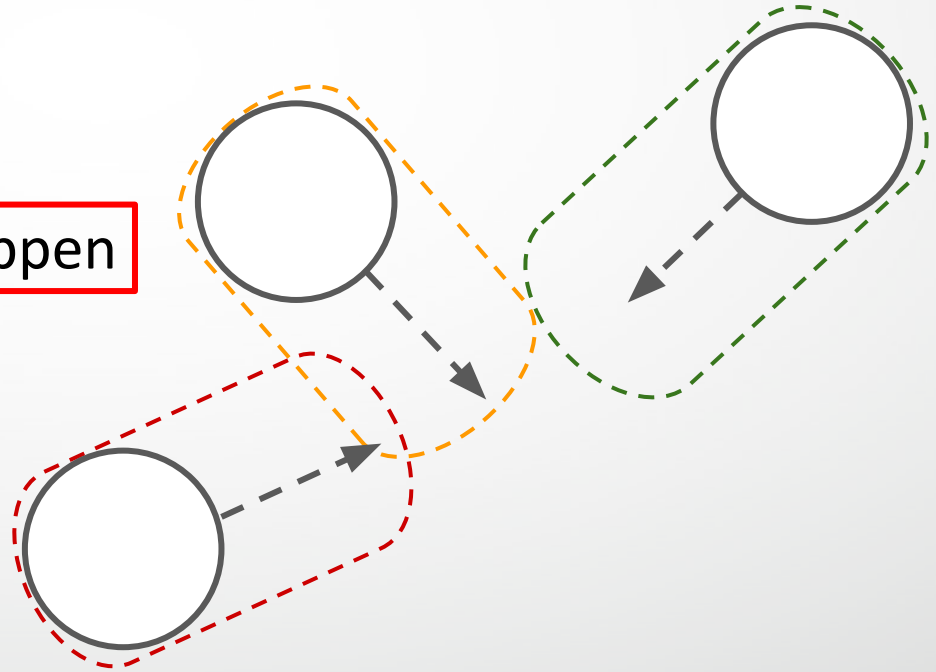
Continuous collision detection

- Intersection test
- Temporal search
- Multiple collisions may happen



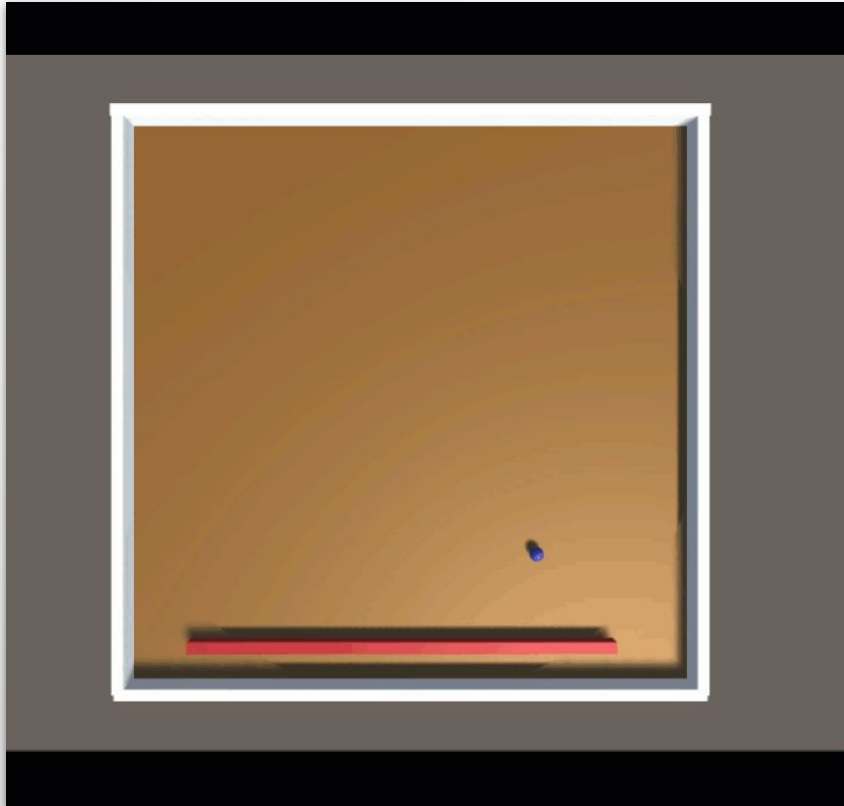
Continuous collision detection

- Intersection test
- Temporal search
- Multiple collisions may happen



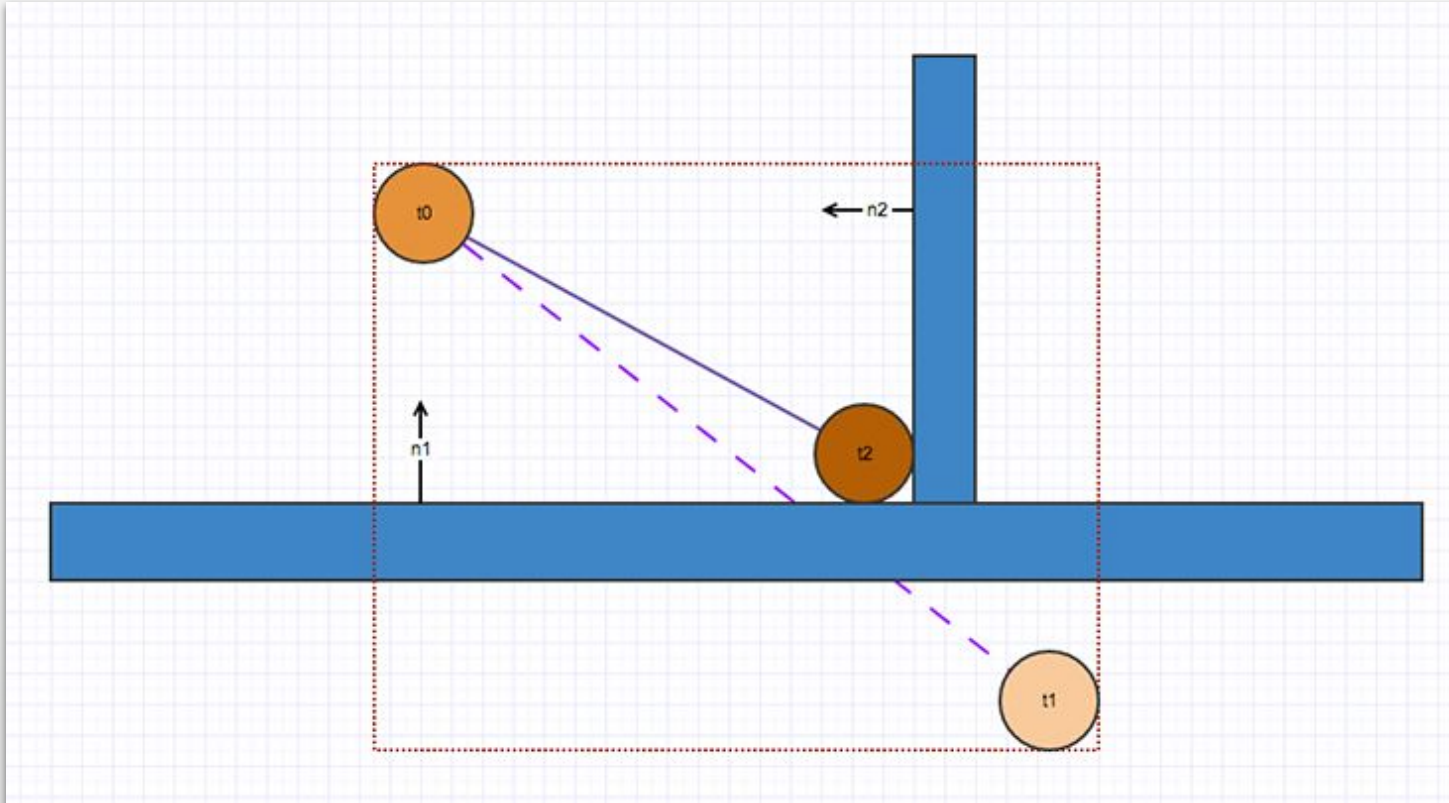


Sweep-based CCD



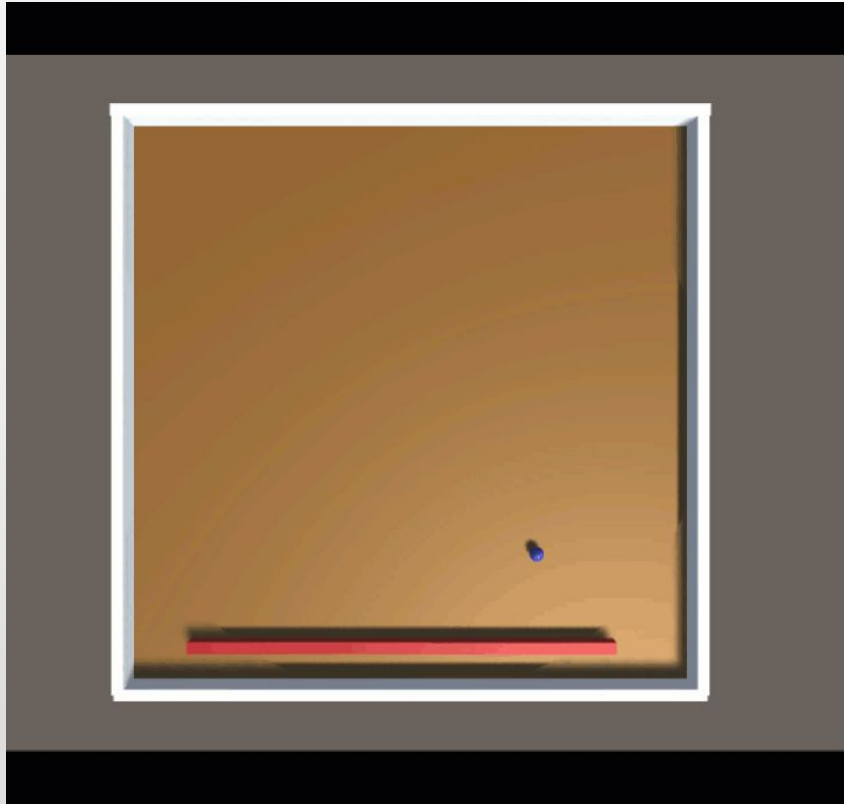


Speculative CCD [1]



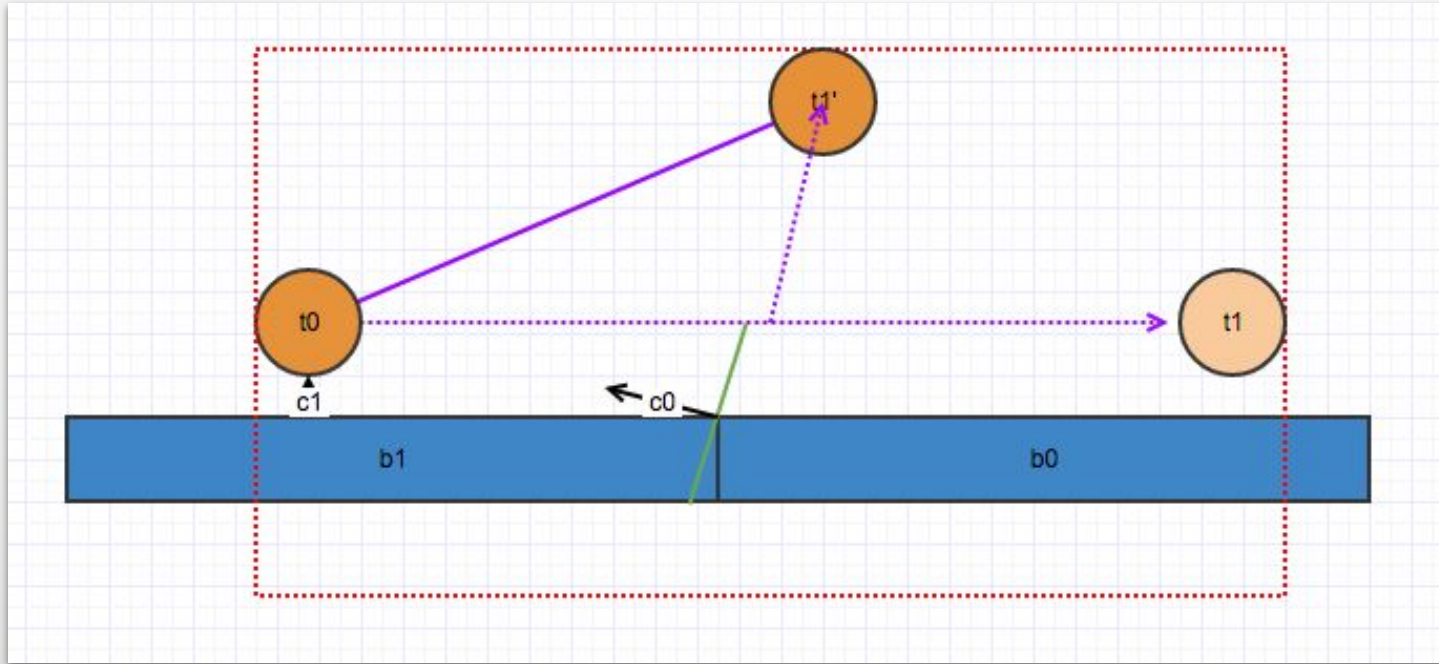


Speculative CCD [2]



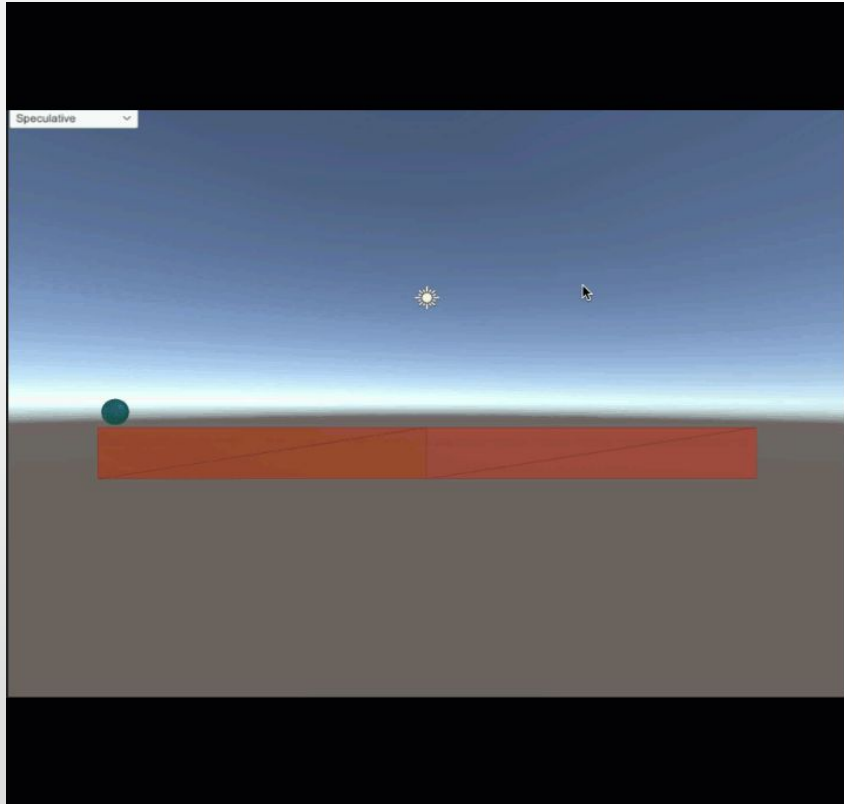


Speculative CCD [3]



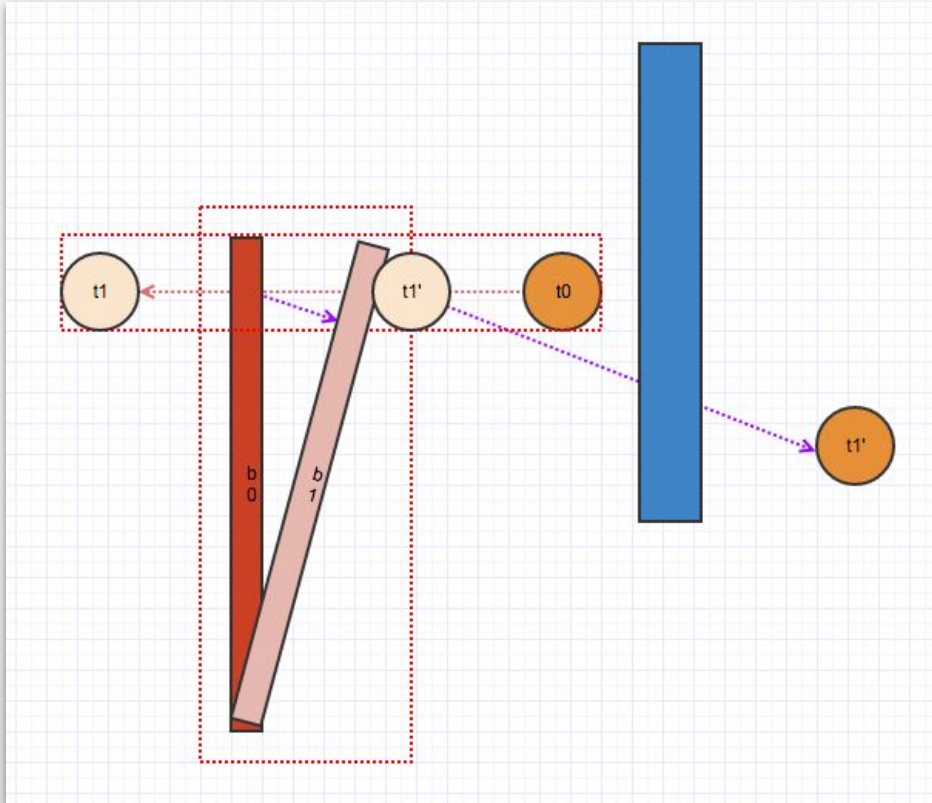


Speculative CCD [4]





Speculative CCD [5]





Rigidbody

A screenshot of the Unity Inspector window for a Rigidbody component. The window has a dark grey background. At the top left, there is a green and white crosshair icon followed by the text 'Rigidbody'. To the right of the title are three icons: a question mark, a filter icon, and a vertical ellipsis. Below the title bar, there are several settings:

- Mass: 1
- Drag: 0
- Angular Drag: 0.05
- Use Gravity:
- Is Kinematic:
- Interpolate: Interpolate (dropdown menu)
- Collision Detection: Discrete (dropdown menu, highlighted with a red border)
- Constraints: (collapsible section)
- Info: (collapsible section)



Demo : 3D Game Kit

- Create a new **Scene**
- Add two **Cube** and make them collide



Physics material

Inspector

Grenade

Open

| | |
|------------------|---------|
| Dynamic Friction | 20 |
| Static Friction | 20 |
| Bounciness | 0.6 |
| Friction Combine | Maximum |
| Bounce Combine | Maximum |



Physics material

Inspector

Grenade

Open

| | |
|------------------|---------|
| Dynamic Friction | 20 |
| Static Friction | 20 |
| Bounciness | 0.6 |
| Friction Combine | Maximum |
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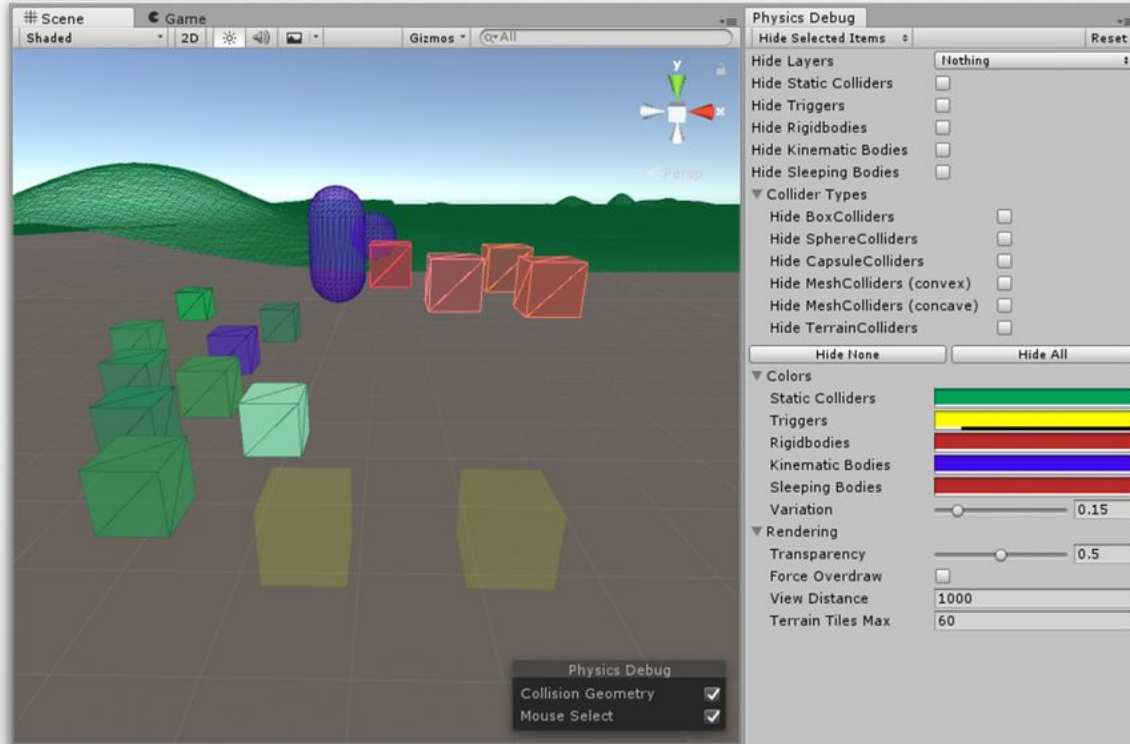


Demo : 3D Game Kit

- Create a new **Scene**
- Add an enemy using **Grenadier** prefab
- Play with Physics material: **Grenade**

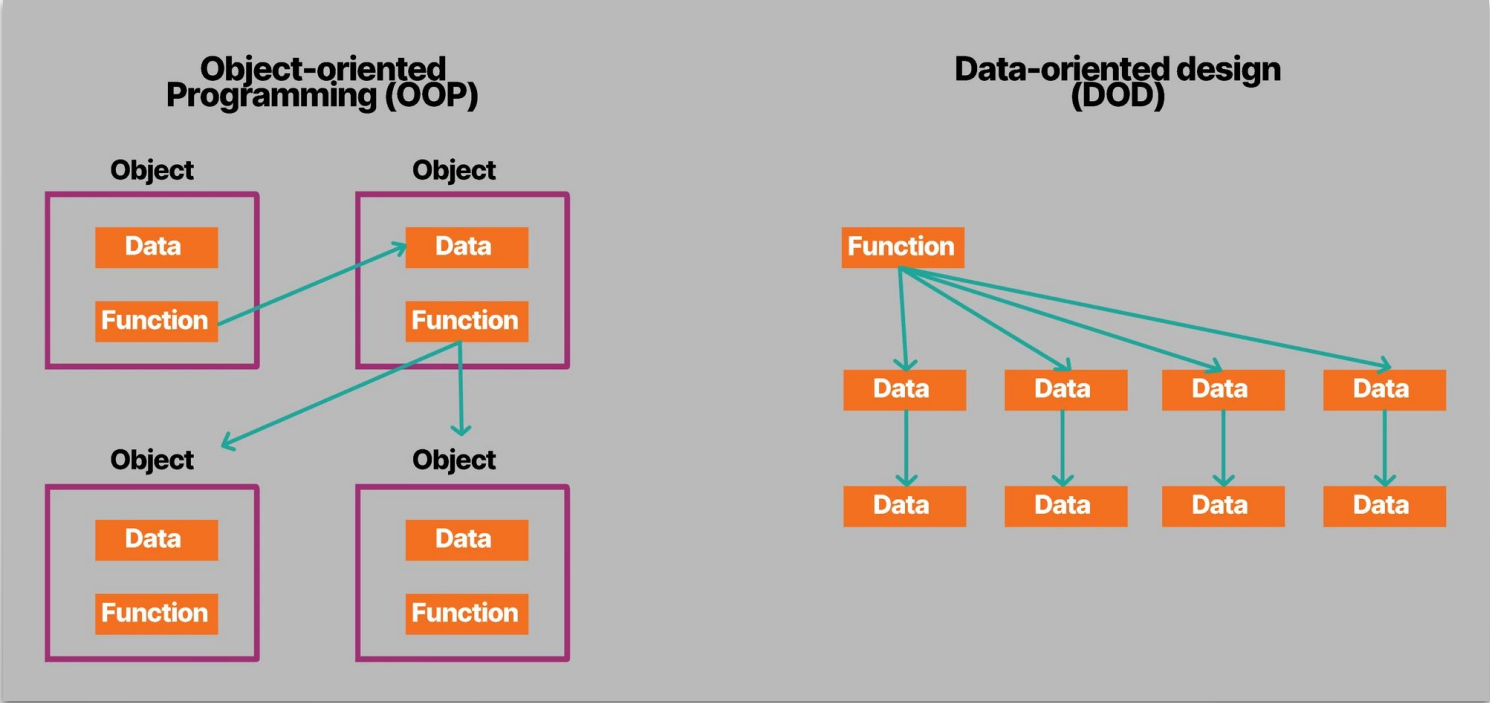


Physics debug visualization



(DEMO)

Data-oriented design





Data-Oriented Technology Stack

- Entity Component System (ECS)
- C# Job System
- Burst compiler

Q & A