Computer Animation Middleware Software

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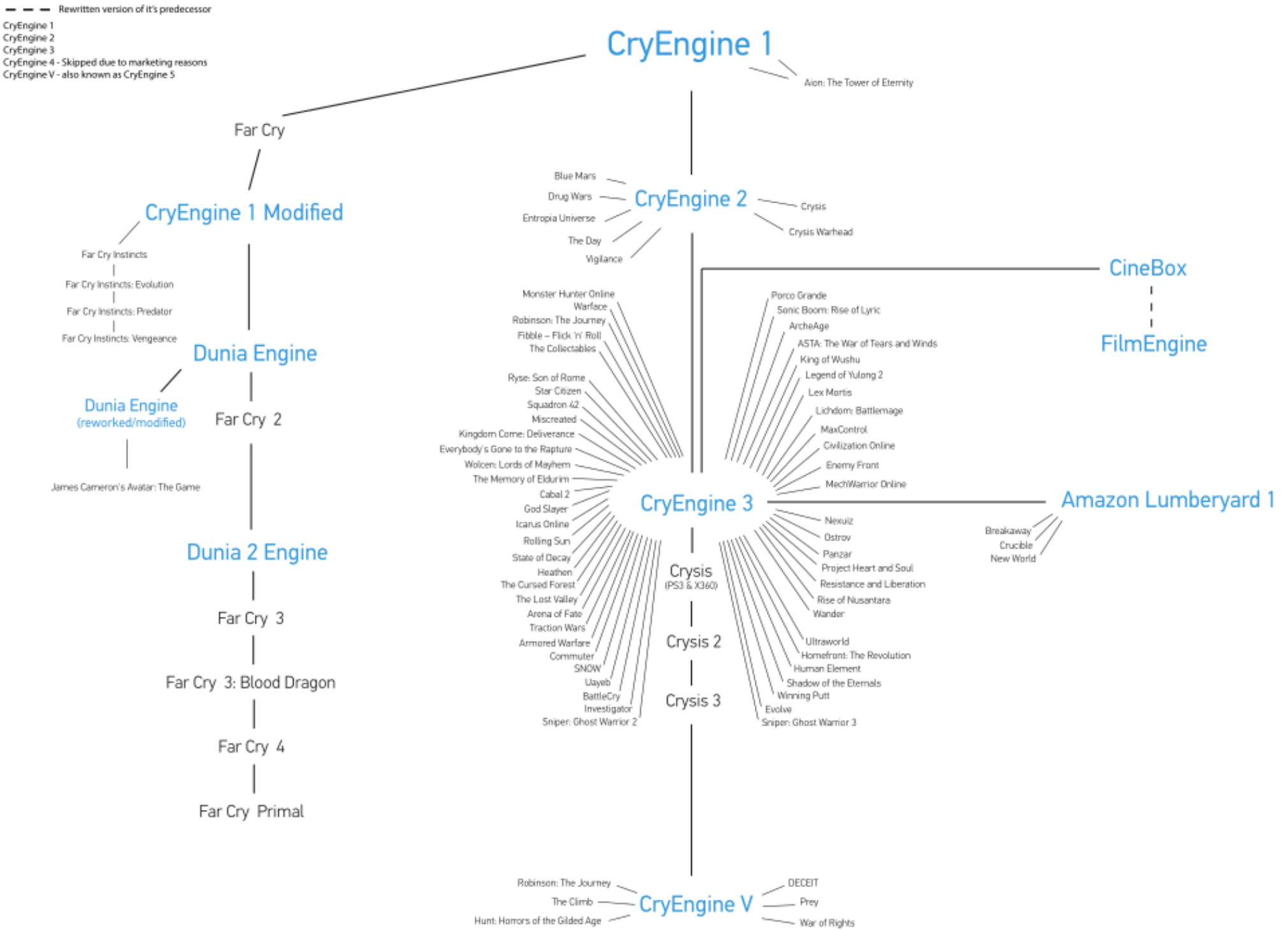
Game Engines

- Unreal Engine (Epic Games)
- Unity (Unity Technologies)
- Source, Source2 (Valve)
- CryEngine (Crytek)
- AnvilNext (Ubisoft)
- Frostbite (Electronic Arts)
- (not an exhaustive list)


Rewritten version of it's predecessor
CryEngine 1
CryEngine 2
CryEngine 3
CryEngine 4 - Skipped due to marketing reasons
CryEngine V - also known as CryEngine 5
CryEngine 1
Aion: The Tower of Eternity
Far Cry
CryEngine 1 Modified
Far Cry Instincts
Far Cry Instincts: Evolution
Far Cry Instincts: Predator
Far Cry Instincts: Vengeance
Dunia Engine
Dunia Engine
(reworked/modified)
James Cameron's Avatar: The Game
Far Cry 2
Dunia 2 Engine
Far Cry 3
Far Cry 3: Blood Dragon
Far Cry 4
Far Cry Primal
Blue Mars
Drug Wars
Entropia Universe
The Day
Vigilance
CryEngine 2
Crysis
Crysis Warhead
CineBox
FilmEngine
Monster Hunter Online
Warface
Robinson: The Journey
Fibble – Flick 'n' Roll
The Collectables
Ryse: Son of Rome
Star Citizen
Squadron 42
Miscreated
Kingdom Come: Deliverance
Everybody's Gone to the Rapture
Wolcen: Lords of Mayhem
The Memory of Eldurim
Cabal 2
God Slayer
Icarus Online
Rolling Sun
State of Decay
Heathen
The Cursed Forest
The Lost Valley
Arena of Fate
Traction Wars
Armored Warfare
Commuter
SNOW
Uayeb
BattleCry
Investigator
Sniper: Ghost Warrior 2
Porco Grande
Sonic Boom: Rise of Lyric
ArcheAge
ASTA: The War of Tears and Winds
King of Wushu
Legend of Yulong 2
Lex Mortis
Lichdom: Battlemage
MaxControl
Civilization Online
Enemy Front
MechWarrior Online
CryEngine 3
Amazon Lumberyard 1
Breakaway
Crucible
New World
Nexuiz
Ostrov
Panzar
Project Heart and Soul
Resistance and Liberation
Rise of Nusantara
Wander
Ultraworld
Homefront: The Revolution
Human Element
Shadow of the Eternals
Winning Putt
Evolve
Sniper: Ghost Warrior 3
Crysis
(PS3 & X360)
Crysis 2
Crysis 3
Robinson: The Journey
The Climb
Hunt: Horrors of the Gilded Age
CryEngine V
DECEIT
Prey
War of Rights

Character Animation Middleware

- NaturalMotion
  (real-time motion control using biomechanics)
  (acquired by Zynga for $527M in 2014)

- IKInema (full-body IK solver)

Physics in games

- Custom, in-house software
- Off-the shelf libraries
- Physics middleware

Physics Engines

- Real-time
  - Video games
- High precision
  - Slow
  - Film
  - Scientific computing

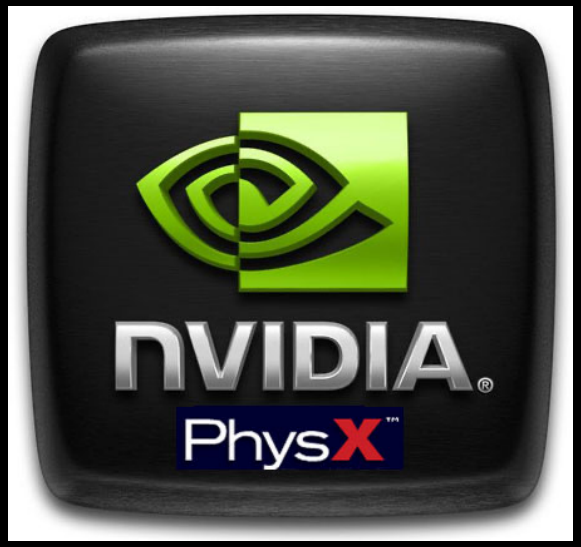
Half-life 2

Real-time physics engines: open source

- Open Dynamics Engine (ODE)
- Bullet
- SOFA
- Vega FEM
- and several others

Real-time physics engines: commercial

- Havok (Ireland) (Intel => now Microsoft)
- Physx (formerly NovodeX, now nVidia)
- Vortex (Montreal)
- Rubikon (Valve)



Components of physics engine

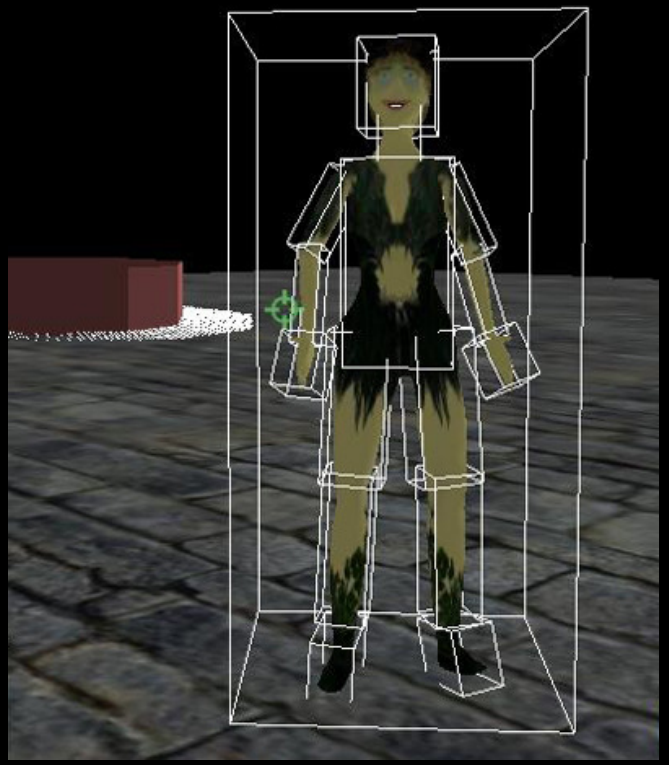
- Collision detection
- Dynamics
  - rigid objects
  - cloth
  - fluids
- Fracture

Rigid object contact

- Penalty-based
  - popular with soft/deformable objects
- Impulse-based
- Constraint-based
  - expensive, suitable for continuous contact

Real-time simulation

- Speed more important than accuracy
- Objects have two representations:
  - Complex geometry (rendering)
  - Simplified geometry (collision detection, dynamics)

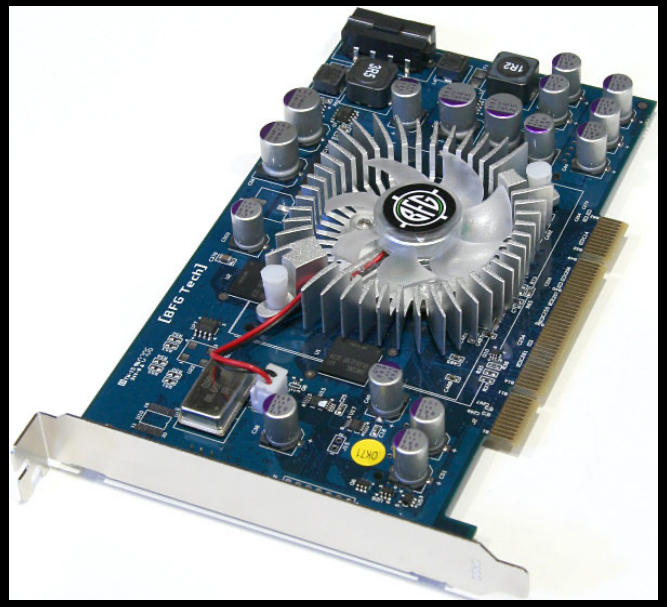


Characters

- Rag-doll physics
  - Rigid objects
- Cloth
- Controller
  - NaturalMotion
- Particles (hair)

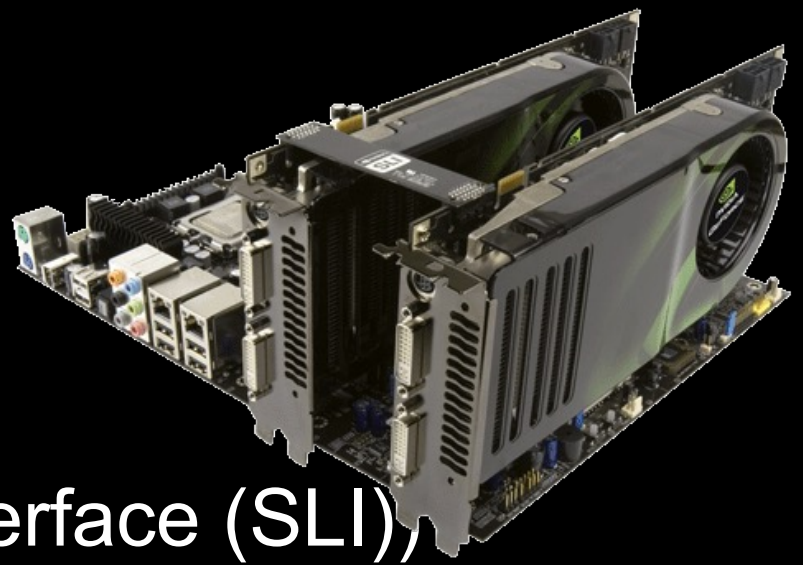
Physics processing unit (PPU)

- Dedicated physics co-processor
- SPARTA and HELLAS
  - academic
  - Penn State, Univ. of Georgia
- Ageia (Switzerland, 2006)
  - later merged into nVidia
  - use AGEIA's PhysX SDK



GPGPU

- Havok FX
  - was cancelled

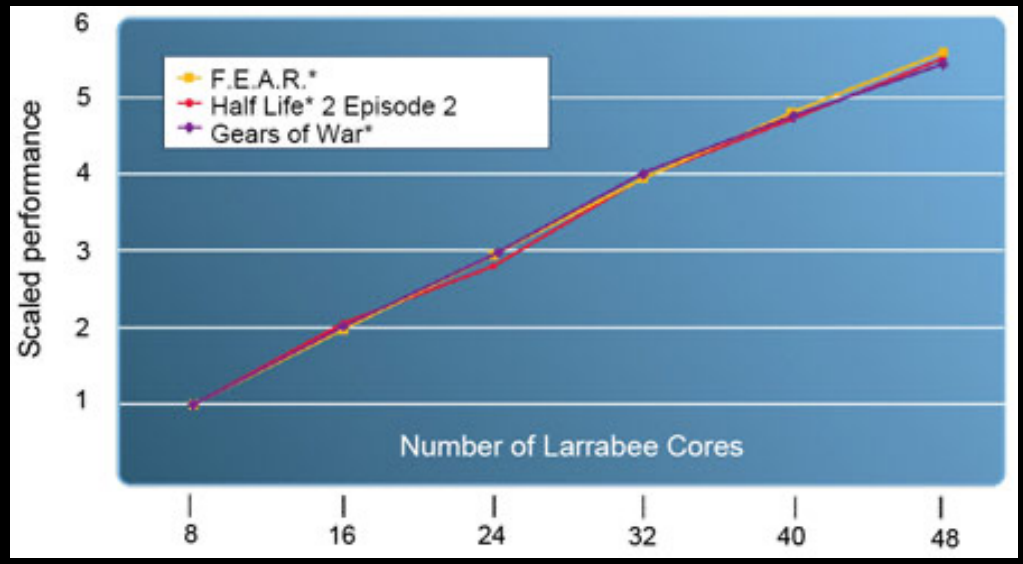


- Multi-GPU technology
  - AMD (CrossFireX)
  - nVidia (Scalable Link Interface (SLI))
  - SLI just parallelizes rendering, but can dedicate a specific card just to Physx (similar to AGEIA)

- Increasingly more suitable for physics

Intel Larrabee

- Many-core x86
- Fusion of CPU and GPU
- Suitable for physics



- Was scheduled for 2010, but canceled
- Combo of CPU and GPU: AMD (APU), Apple (M1, M2, M3), Intel (Falcon Shores, ~2025)

Havok

- Real-time commercial physics engine
- Company bought by Intel (2007) ($110 million), later sold to Microsoft
- Used in over 300 games
  - Halo
  - Half Life 2

Havok Engine

- Animation
  - Fast playback
  - Real-time blending
  - Inverse kinematics
  - Retargeting

- AI
  - path-finding

Havok Engine

- Behavior
  - Character behavior development tool
- Cloth
- Destruction
- Physics

Havok Physics

Havok Physics

- Collision detection
- Constraints
- Rigid bodies
- Cloth
- Continuous physics

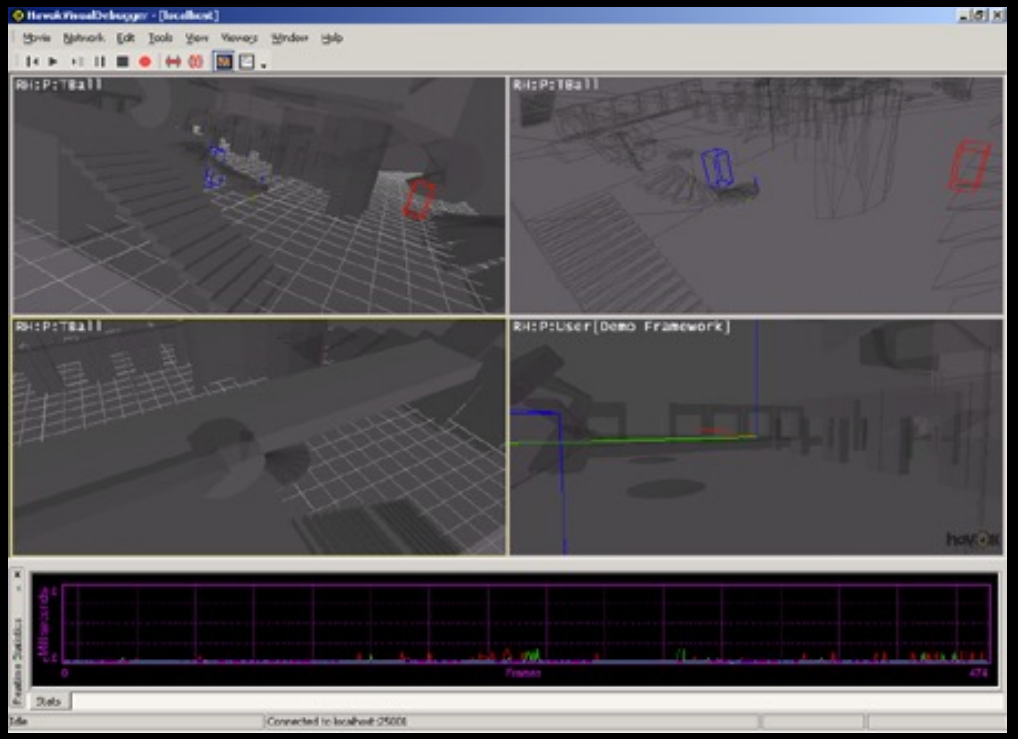
Uncharted 2: Among thieves

Havok Physics

- Vehicle simulation
- Human ragdolls
- Character controller
  - simulate enemy characters being hit

Havok Physics

- Visual debugger and profiler
- Content creation tools
- Integration with 3rd-party renderers
  - 3D Studio Max
  - Maya



Havok Physics

- Extensively optimized (machine code)
- Microsoft Xbox
- Sony PLAYSTATION
- Nintendo Wii
- PC

```
main:   subu    $sp, $sp, 32
        sw      $ra, 20($sp)
        sw      $fp, 16($sp)
        addiu   $fp, $sp, 28
        li      $v0, 4
        la      $a0, str
        syscall
        li      $a0, 10
        jal     fact
        addu    $a0, $v0, $zero
        li      $v0, 1
        syscall
        lw      $ra, 20($sp)
        lw      $fp, 16($sp)
        addiu   $sp, $sp, 32
        jr      $ra
```

Havok Physics is not…

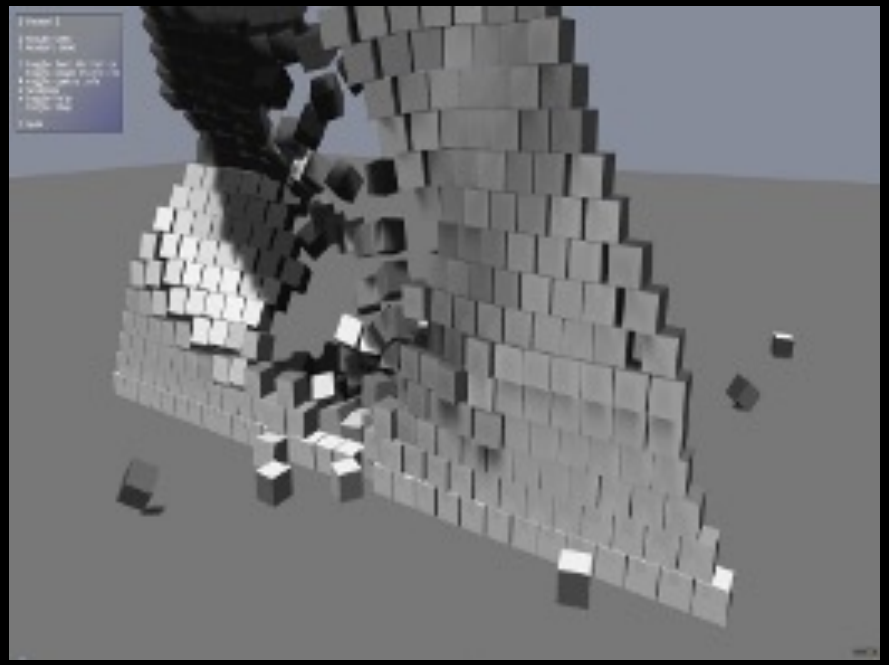
- Simple technology
  - Must invest time to use it
- Black box
  - Must understand the components and recombine them
- Commercial renderer

Havok Physics

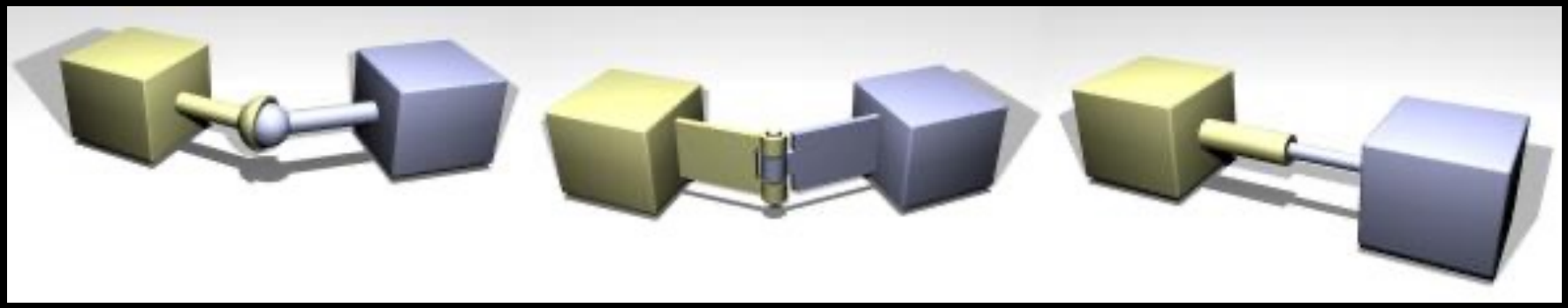
- The “Havok World” (hkpWorld)
- Contains all physical objects in the simulation
- Timesteps the simulation forward in time

Rigid objects

- The central object in Havok
- hkpRigidObject class
- Add to the “world”
- Set mass, inertia tensor, etc.



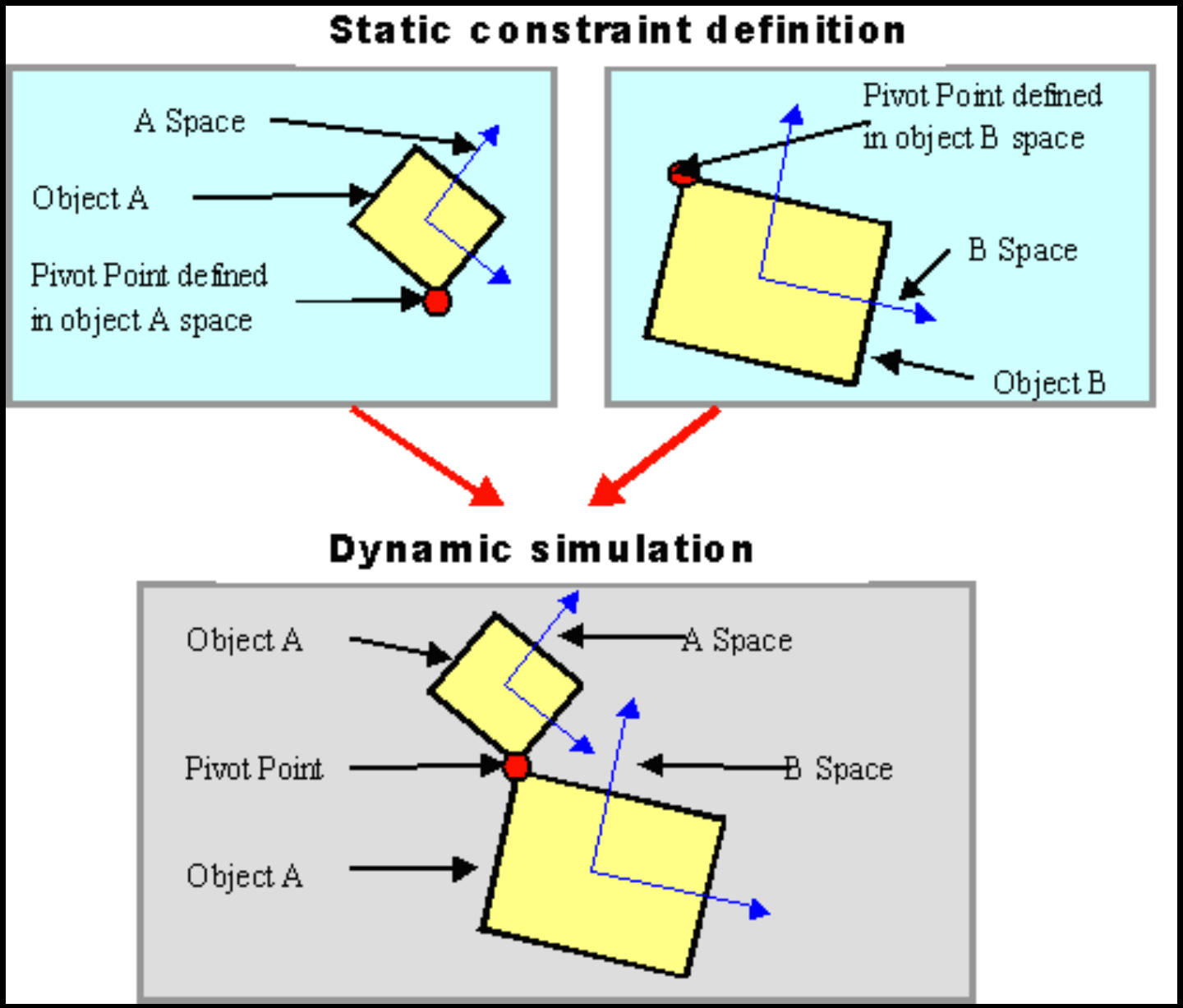
Constraints



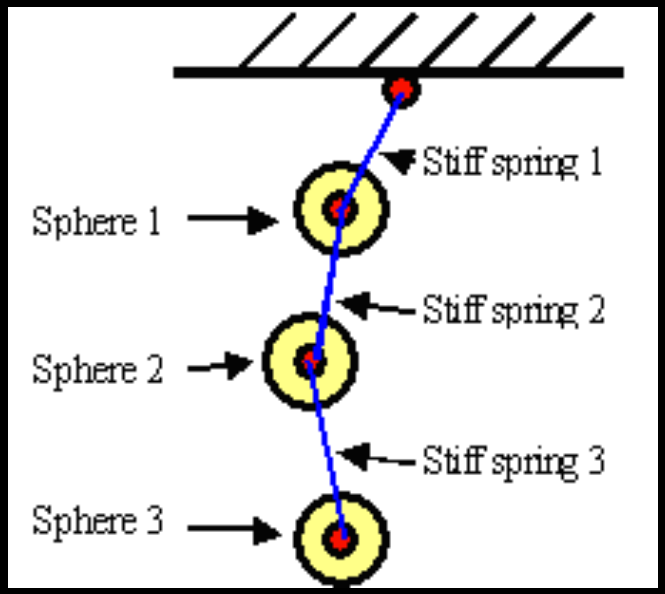
Ball and socket

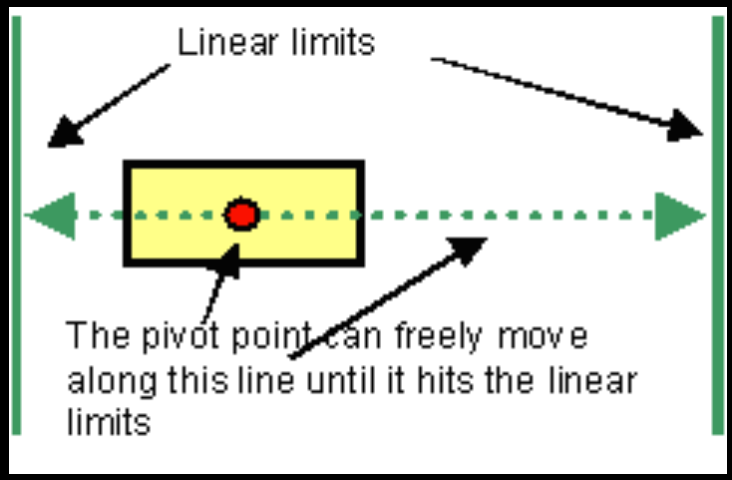
Hinge

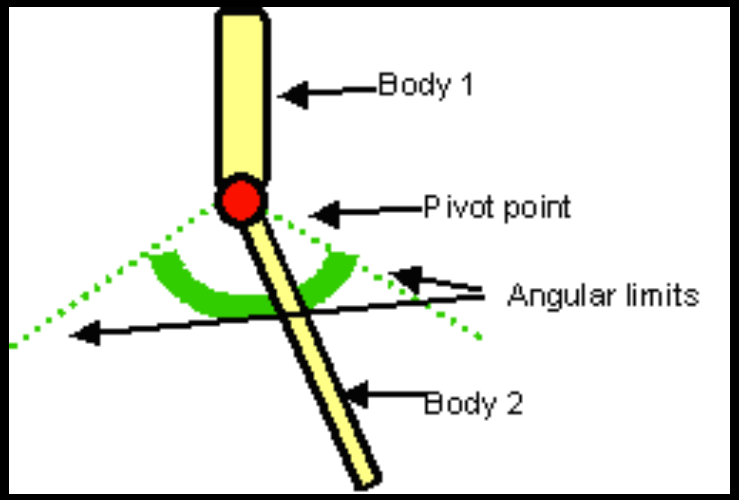
Translational


Static constraint definition
A Space
Object A
Pivot Point defined
in object A space
Pivot Point defined
in object B space
B Space
Object B
Dynamic simulation
Object A
A Space
Pivot Point
B Space
Object A

Constraints

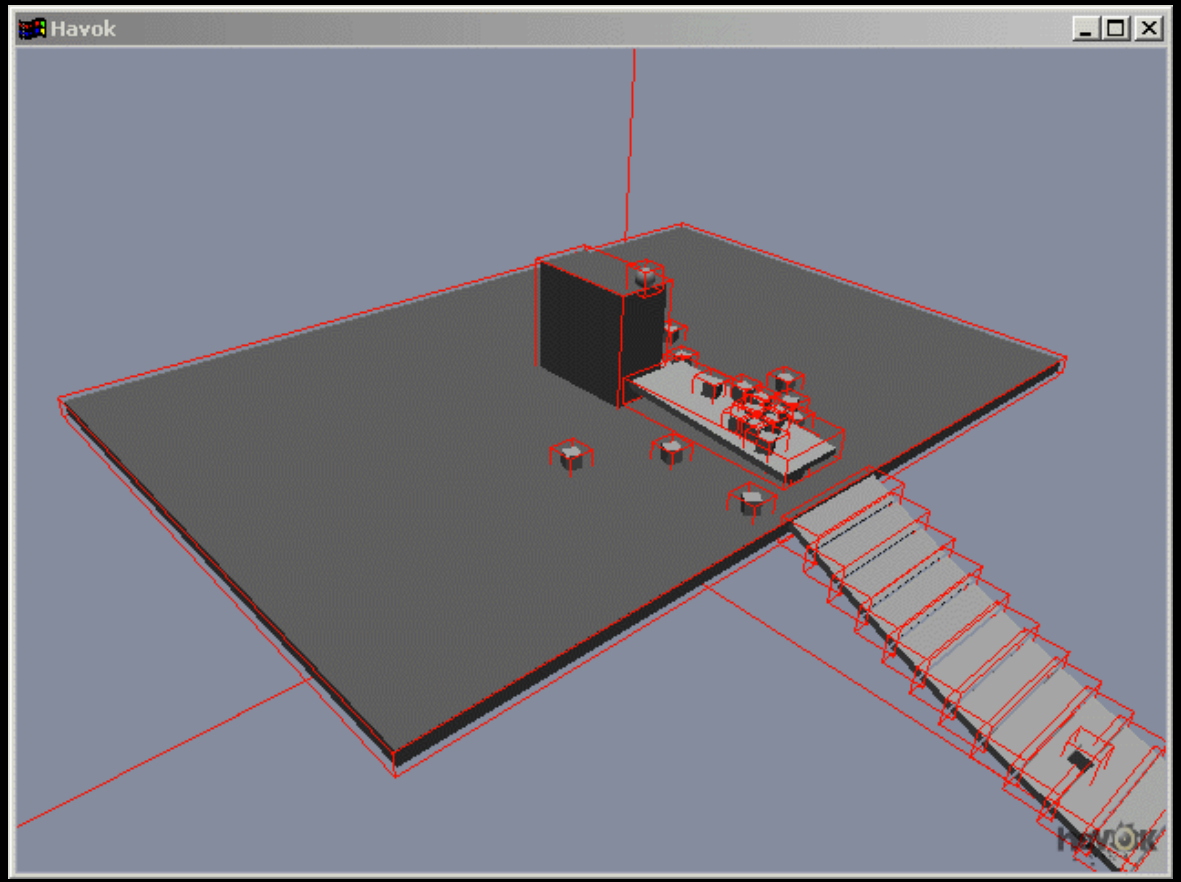






Collision Detection

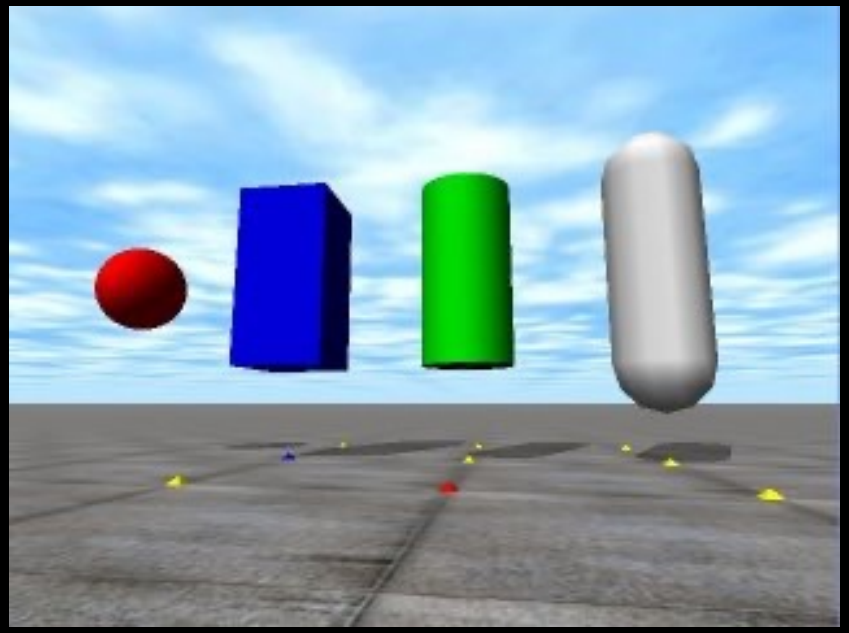
- Broad phase and narrow phase



Broad phase

Collision Detection

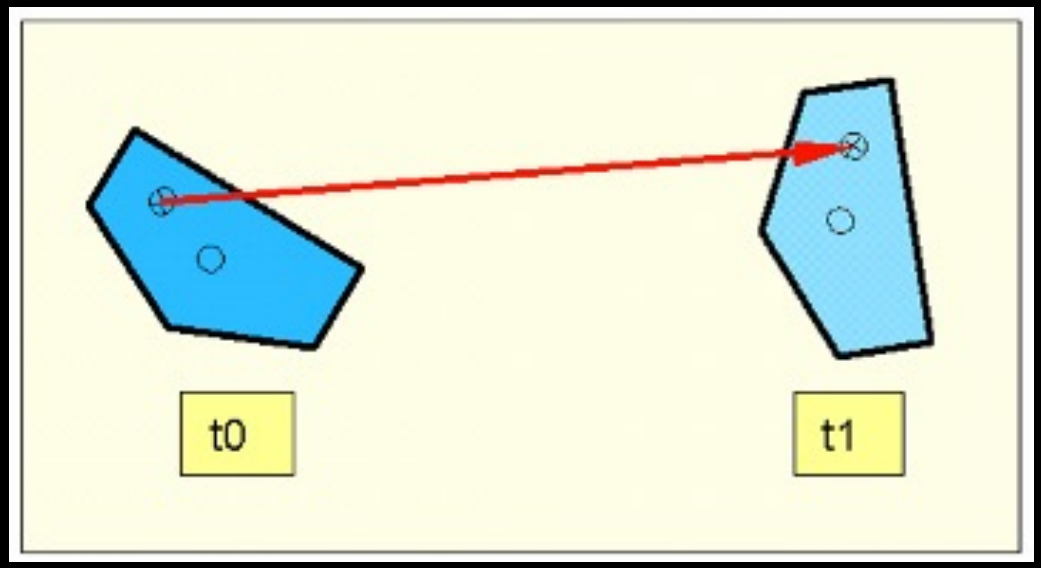
- Narrow phase
- Spheres
- AABBs
- Cylinders
- Capsules
- Compound shapes



Collision Detection: Queries

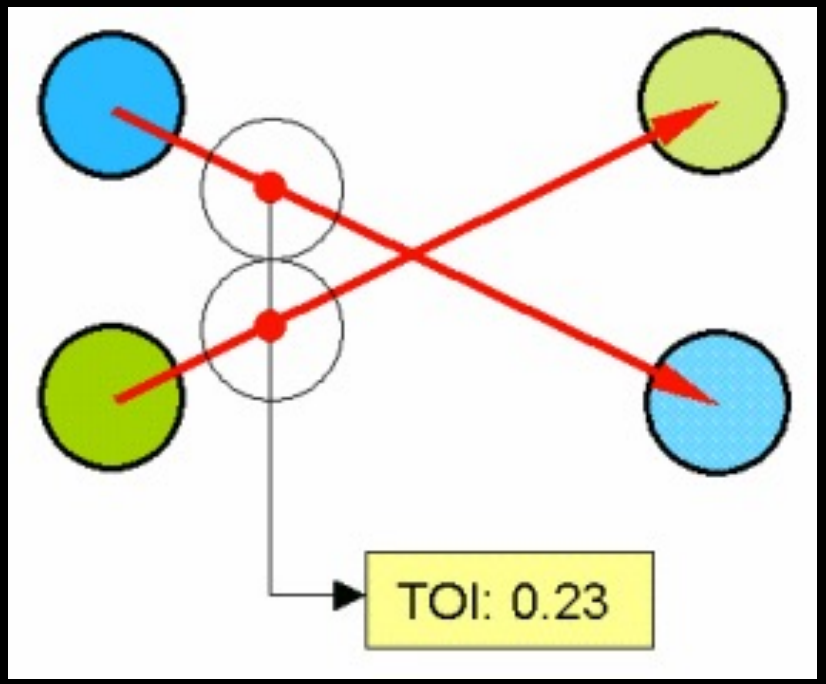
- Closest points between two bodies
- Whether two bodies penetrate
- Raycast a point through space and get colliding objects

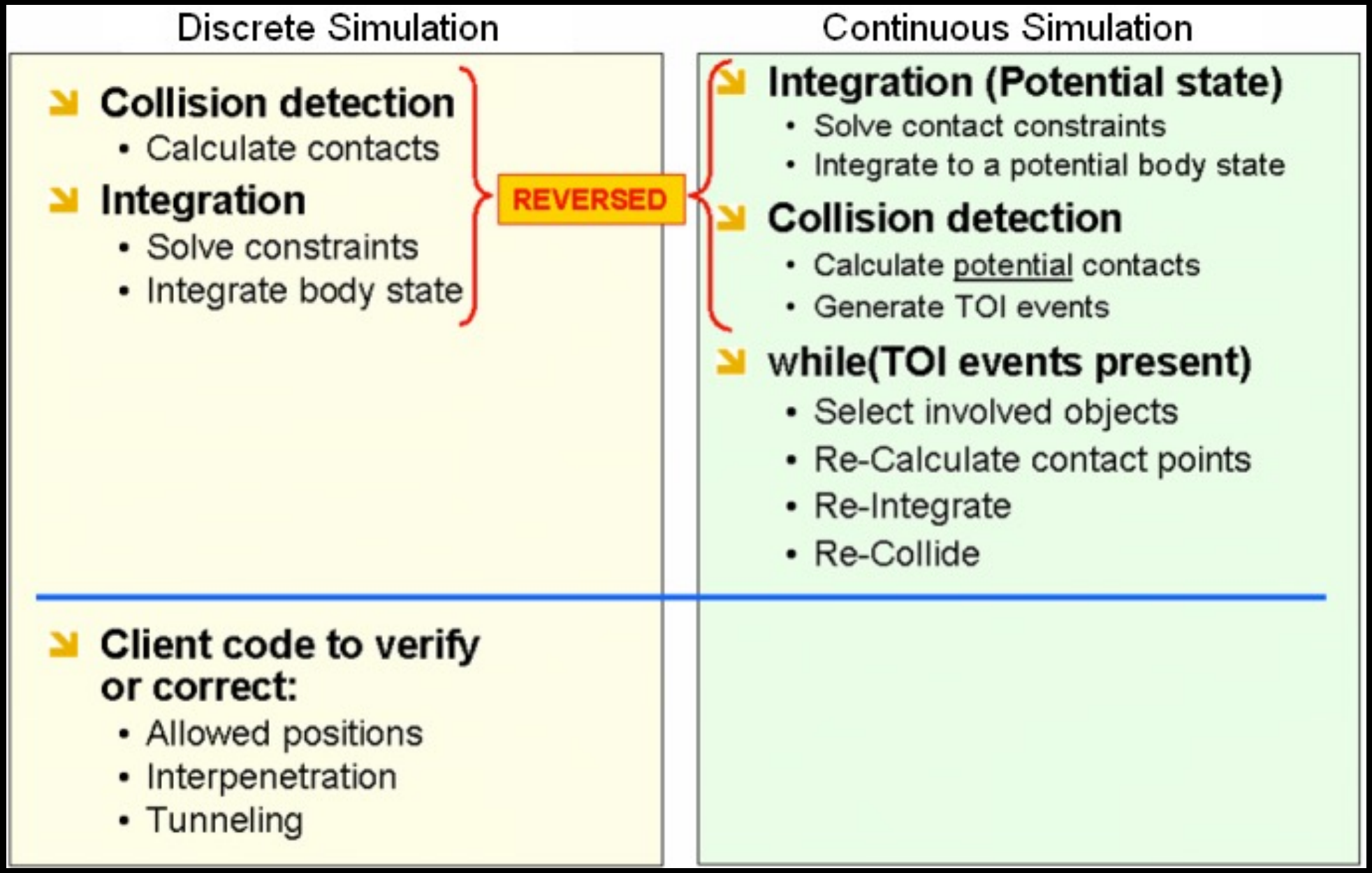
Continuous Physics



Continuous Physics

- Time of impact:




Discrete Simulation
Continuous Simulation
Collision detection
Calculate contacts
Integration
Solve constraints
Integrate body state
REVERSED
Integration (Potential state)
Solve contact constraints
Integrate to a potential body state
Collision detection
Calculate potential contacts
Generate TOI events
while(TOI events present)
Select involved objects
Re-Calculate contact points
Re-Integrate
Re-Collide
Client code to verify or correct:
Allowed positions
Interpenetration
Tunneling