Computer Animation
Middleware Software

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Game Engines

- Unity (Unity Technologies)
- Unreal Engine (Epic Games)
- Source, Source2 (Valve)
- CryEngine (Crytek)
- AnvilNext (Ubisoft)
- Frostbite (Electronic Arts)
- (not an exhaustive list)
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
- AMD: APU (combo of CPU and GPU)
Havok

- Real-time commercial physics engine
- Company bought by Intel (2007) ($110 million)
- 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

- First Person Shooters
- Driving Games
- 3rd Person Action Games
- Real Time Strategy Games
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
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

- Linear limits: The pivot point can freely move along this line until it hits the linear limits.
- Angular limits: Body 1 and Body 2 have angular limits defined by the pivot point and the dashed line.

Diagram showing spheres and stiff springs connected, illustrating constraints in a mechanical system.
Collision Detection

• Broad phase and narrow 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

- **Collision detection**
  - Calculate contacts

- **Integration**
  - Solve constraints
  - Integrate body state

Client code to verify or correct:
- Allowed positions
- Interpenetration
- Tunneling

Continuous Simulation

- **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