Additional Topics:

Computing Principles and Practice of a Blockbuster Video Game

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Core Technology Group
Black Rock Studio
The Walt Disney Company
Split/Second: Velocity
Released May 2010
Video Game Industry

• Digital Economy
  – Creative Industries
    • Growth

• Retail Delivery
  – Developing online
    • Convenience

• Blockbusters
  – Modern Warfare £111m US
  – Grand Theft Auto IV £108m GB (2008)
  – FIFA £58m CAN
  – Wii Fit £45m JPN
  – Assassin’s Creed £36m CAN
  – Need for Speed £18m GB
  – Batman £15m GB  
    (2009/2010 UK sales source Develop 100)
Industry Trends

• Data in cloud, persistence, levelling-up
• Episodic and user generated content
• Simple natural interfaces
• Hyper-reality
  – Photorealistic, stylised
  – Can machines simulate interactive reality?
Real-time

• Define
  – 10hz : Interactive
  – 24hz : Film
  – 30hz : Games
  – 60hz : High refresh rate critical games
  – 120hz : High quality 3D stereoscopic games
  – Needs to be constant, no spikes to break immersion

• Input

• Latency
Game Development

- mathematical methods
- object oriented programming
- databases
- systems
- concurrency
- human-computer interaction
- algorithms
- digital signal processing
- operating systems
- networking
- multi-processors
- artificial intelligence
Programmer Development Time

- Exponential increase in programming time per game
### Code

#### Tools+Pipeline: Python

#### Runtime: C++

#### Shaders: CG, HLSL, ASM

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### Game

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http://cloc.sourceforge.net
Team Size

• Doom (1993)
  – ~10 developers

• Harry Potter (2005)
  – ~70 developers
  – Brook’s vs “Potter’s” law

• Split/Second (2010)
  – Peak ~150 dev staff
  – Outsourcing
  – Short term contracts

Courtesy Michael Carr
Methods

• AGILE
  – Small focused teams, responsive to changes
• Wiki use
  – Efficient communication portal between teams
  – Tasks, blogs, reports
• Automated testing infrastructure
  – Test driven development
  – Unit tests
  – Continuous code & asset builds validating content
  – Render & profiling deviation tests
Stages

Pre-production
1. Art style, x-movie, R&D, proof of concept
2. Tools production, mature pipeline, vertical slice build

Production
1. Large art/design/outsourced content team
2. User testing and feedback
3. Optimization, polish, quality assurance testing

Post-production
n. Downloadable content (DLC), community, patch
Platforms

- **Focus**
  - Relatively aligned
  - Outsourced ports

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Bottlenecks

• Build
  – Code, Assets, Live Update

• Memory
  – Media, RAM, VRAM

• Simulation
  – AI, animation, physics

• Rendering
  – Geometry
  – Shading
Not Bottlenecks (unless...) 

• Game logic, control, progression 
  – Increasing to 1000s of entities 

• Simple joypad input 
  – Image processing, skeletal tracking, biometrics 

• Audio 
  – Speech recognition, synthesis, voice location
Optimization

• Knuth/Hoare
  – ‘Premature optimization is the root of all evil’
• ‘Moore’s law is dead’, Gordon Moore
  – Increase use of parallelism to multi-core and many-core
• Amdahl’s law
  – Parallel speed up is limited by sequential portion of process
• Gustafson’s law
  – Sequential portion relatively small when massively parallel
Game Parallel Processing

- Directed graph of task & data parallel steps
- Data Parallel
  - Performs same task on
    - Separate blocks of a large dataset
    - Physics, Geometry & Shading
- Task Parallel
  - Performs different tasks on
    - Same or separate data
    - Audio, Particles, Visibility
- Instruction Parallel
  - Pipelining, superscalar
  - Out-of-order execution (n/a)
Pipelining

- Pipelined (temporal) parallelism
  - CPU 1
    - Pipeline Stage One
  - CPU 2
    - Pipeline Stage Two
  - CPU 3
    - Pipeline Stage Three

- Parallel (spatial)
  - CPU 1
    - Parallel Process One
  - CPU 2
    - Parallel Process Two
  - CPU 3
    - Parallel Process Three
Pipelined Game Processing

- Increases throughput, but introduces latency
Latency

• Stages of an interactive loop
  – Player
    • Sensory impulses -> reaction time -> motor control
  – Input
    • Physical input -> device capture -> signal process
  – Simulation
    • Interpret input -> compute response -> update state
  – Render
    • Dispatch drawing commands -> video signal -> display lag

• 1 to 5 frames depending on
  – Required responsiveness
  – Device and hardware characteristics
Elements of a Blockbuster

• Shading
• Lighting
• Physics
• Particle
• Cameras
• Speed
Car Shading

- 2 Tone Paint
  - Fresnel
  - Clear coat
  - Dynamic reflection

- Damage
  - Smoke
  - Lacquer scratches
  - Scrapes
  - Glass

© Disney
Lighting

- Deferred Shading
  - Reduces per-pixel shading cost to only visible surfaces
- First Pass
  - G-Buffer
- Shading Pass
  - Dynamic
  - Many lights
Lighting

• Rigs
  – Day
  – Night
Lighting

• Some lighting elements baked offline
  – Static global illumination
  – Too costly to compute (our R&D work)
Lighting

• Tiled classification of image elements permits reduced shading cost
  – Soft shadow edge filtering
  – Geometry edge anti-aliasing
Rock Blast

- Grey box
- Prototype simulation
- Billboard particles
Rock Blast

- Textured
- Validate fracture visuals
Rock Blast

- Apply particle effects

© Disney
Rock Blast

• Combine with environment
Rock Blast

- In game
  - Debris away from track, interactive boulders, particles
Particles

- Non-interactive particles add to the visual composition
Interactive Physics

- Distorting particles
  - Apply turbulence force of volume displaced by cars

© Disney
Rubber Neck Camera

• Accentuate highlights with bullet time camera zoom
3 Way Track Changes

• Destructive events change track layout
  – Updating AI car paths and collision geometry
1.5Km of Destruction

• 1000+ animating joints processed in parallel on SPUs
1.5Km of Destruction

• Pushing the edge of floating-point precision for collision volumes
Velocity
Questions?

• Thanks to the Black Rock Studio Team

• Kenny.Mitchell@disney.com
• Dawn.Beasley@disney.com