CS 248
Interactive Computer Graphics

Instructor: Ron Fedkiw

Website: cs248.stanford.edu

Meeting Times: Tuesday and Thursday,

12:00pm to 1:20pm

CS 148 vs. CS 248

- Rendering is an important part of creating a video game
- CS 148 focused on rendering
- CS 248 thus will not deal much with rendering
- We use scanline rendering in this course
- Ray tracing is typically too slow for real-time rendering in video games --- but can be used to generate high-quality textures for the scanline renderer
  - albeit real time ray tracers do now exist

CS 248: Overview

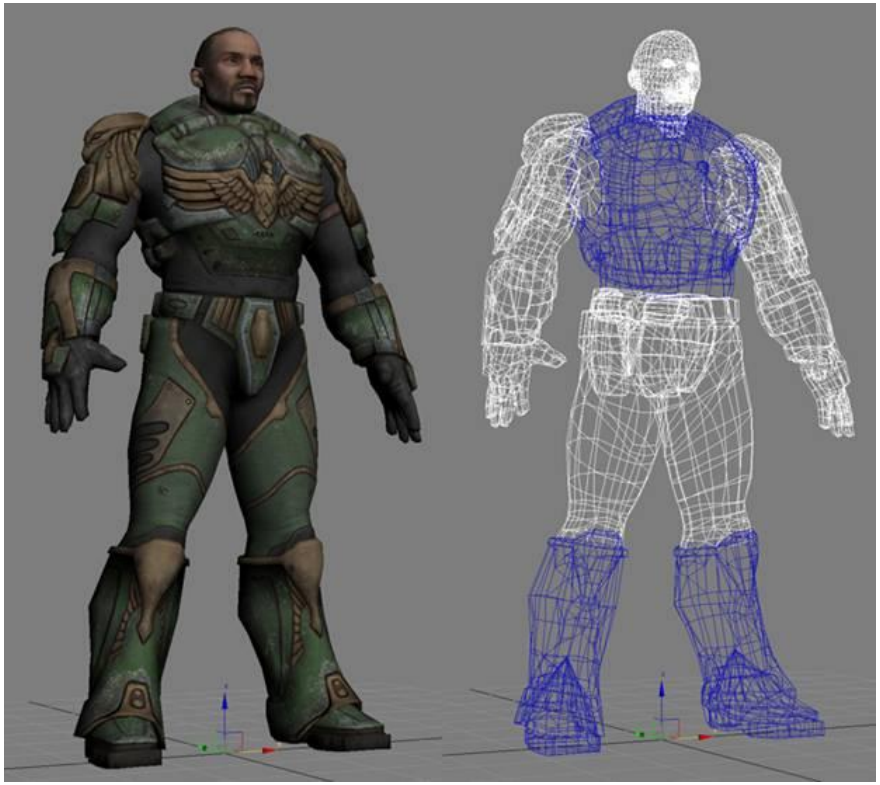
- **Goal: Create a video game!**
- Combine rendering knowledge from CS 148 with ideas from *the rest* of computer graphics including
  - Geometry
  - Animation
  - Simulation
- CS 248 will focus on making things move
  - i.e. Animation and Simulation (along with the necessary computational geometry to make this happen)

Environment Geometry

- The environment in which a game is set is often one of the most compelling components of the game
- An immersive world makes the game both engaging and exciting
- Worlds can be created manually by an artist and/or be procedurally generated

Character Geometry

- Avatars and their opponents represent important game geometry
- They interact with the world via collisions, etc., which require computational geometry algorithms

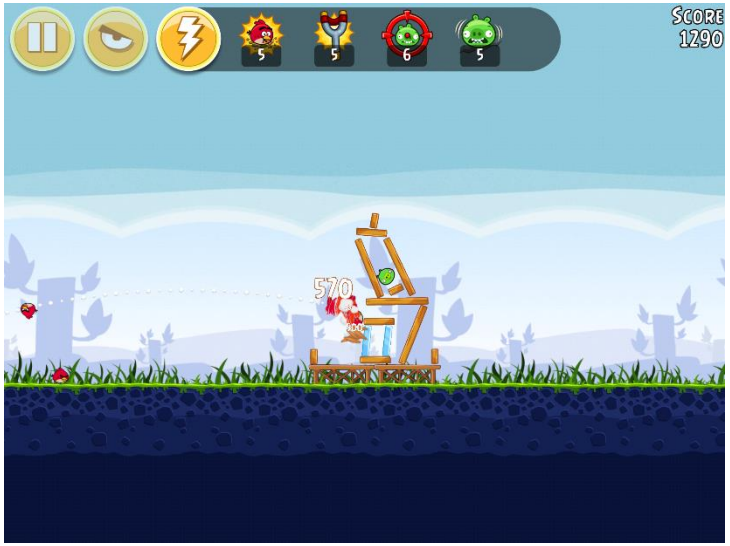


Animation

- Animation is necessary to add motion to the geometry
  - Hand animated by an artist
  - Captured from a performer or puppeteer
  - Simulated with equations/rules

Simulation

- Simulation is another way of moving the geometry
  - although just one method of animation, it has taken on a life of its own
- Instead of specifying positions/velocities explicitly, physics equations (or other rules) are used to get these values
- Allows for more interesting interaction with the environment



CS 248 Outline – Part I

- Week 1 Introduction
  - HW #1 – unity game engine – 5% of final grade
- Weeks 2 & 3 Animation
  - Basics, Animation Curves and Splines, Etc. – 5% of final grade
  - HW #2 Animation – 10% of final grade
- Weeks 4 & 5 Simulation
  - Particles & Particle Systems (cloth, flocking, etc.), Rigid Bodies – 5% of final grade
  - HW #3 Simulation - 10% of final grade
- Weeks 6 & 7 Character Animation/Simulation
  - Characters and Articulated Bodies, Animation and Simulation Thereof – 5% of final grade
  - HW #4 Character Animation/Simulation - 10% of final grade
- (*) You may work with a partner. Grading will consist of in person live demos late Monday afternoons with the CAs (just like CS148). See the web site for more details.

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  - HW #4 Character Animation/Simulation - 10% of final grade
- (*) Short or Long Form Written Assignments. See the web site for more details.

Short or Long Form Written Assignments

- The goal is to get you thinking about the class material, and thinking about how it relates to your game early on…
- 15% of the grade in total
- Written Assignments for 9 of the lectures:
  - Basics, Animation Curves and Splines, Etc. – lectures 3, 4, 5
  - Particles & Particle Systems, Rigid Bodies – lectures 7, 8 ,9
  - Characters and Articulated Bodies – lectures 11, 12, 13
- Short Form – I'll ask some questions in and during class. Write down brief answers on a piece of paper. Turn in at the end of class. (Length – short – a few minutes of writing.)
- Long Form – Will cover the Short Form questions. But will also ask for some detailed discussions related to the lectures, in order to ensure the synergy between the lecture itself and the Short Form questions. (Length – long – a couple pages of writing.)

Gaming Platforms

- The constraint of interactivity requires one to put extensive effort into the platform chosen for the implementation of the game
  - Multithreaded PC Games
    - Make use of all available resources on the PC including both the CPU and the GPU, make use of all cores on the CPU using multithreaded parallelism
    - Very high end graphics
  - Mobile Games
    - Often simpler than PC games due to the limited computing resources available, very different style of user input and interactivity, using sensors on the device is a must
    - 2D games making use of sensors and touch screens
  - Client/Server/Browser Games
    - Communicate between multiple computers and browsers, the browser has many tools to aid in multiplayer communication, many networking challenges
    - E.g. racing games, mmos, etc.
  - Console Games
    - Xbox One, PS4, Nintendo Switch
    - Very specialized and standardized computing environments
    - allows for mass production of very low cost machines (consoles) with optimal resources
    - the game designer can make many assumptions ignoring any hardware variations in order to optimize the game and gameplay

Platform: Multithreaded PC

- Multi-core CPUs are the norm for today's computers. Any game produced today will be released in a market dominated by multi-core processors. N.B. both PS4 and Xbox One look like a PC!
- Work can be divided into multiple tasks which are subsequently distributed among multiple threads
  - Functional Decomposition: Different threads dedicated to physics, sound, rendering, networking, AI, GUI, etc.
  - Data Decomposition: Further increases the concurrency of each function subsystem
- PCs have much more powerful computing resources (CPU and GPU) compared to other platforms allowing PC games to be much more complex and realistic
- Your game should be visually/technically impressive, use threads, and be 3D (no 2d games!)
- There are many tools for implementing threading, such as POSIX Threads (Pthreads), Native Win32 Threads, OpenMP, OpenCL, IntelTBB, etc.

Platform: Mobile Devices

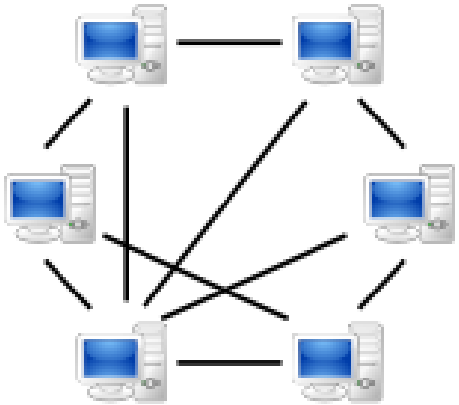
- More opportunities for user interaction compared to a PC game
  - Touch screen: Allows for flexible tactile input and feedback
  - Multiple sensors: accelerometer, gyroscope, magnetometer, etc.
  - Cameras: Interact with and use information from the real-world
- Often rely more on immersive gameplay than superior graphics
  - Simpler game scenes (typically 2D instead of 3D)
  - Less computing power compared to a PC
  - Fast simulation models (e.g. shape matching for deformable body, SPH for fluid. Conventional simulation models on the PC are too expensive for mobile)
  - OpenGL ES standard is a subset of OpenGL
- Your game should make use of the special interactive and sensor driven features of the mobile device (tablets are preferable), and can be 2D

2D Games

- 2D games are allowed under certain circumstances, since rendering is not the focus of this course
- Need to do a very good job incorporating the topics covered in this course (computational geometry, animation, and simulation) into the game
- 2D games are not allowed for the “Threaded PC” option, since the whole point of the PC is to showcase computational power
- For “Mobile”, we strongly recommend (prefer) 2D in order to lighten the load on rendering and stress other aspects of the game

Platform: Client/Server/Browser

- Client-Server Model
  - Server maintains connections with each of the clients
  - Clients do not communicate with each other, but can only communicate indirectly through the server
- Peer-to-Peer Model
  - Peers are coequal nodes
  - Communication does not rely on a server
  - Decentralized system
- Browsers have lots of tools useful for implementing client/server or peer-to-peer games
- Running a browser game alone on a PC is not an efficient use of resources. All browser games should be either client/server or peer to peer. They can be 2D.



Platform: Client/Server/Browser

- Advantages: Cross-platform and convenient
  - Can play a game as long as you have access to a browser; no need to download any client program
  - Do not need to deal with the underlying operating system, just the browser itself
  - The ability to communicate with a server or other players makes browser games versatile
- Disadvantages
  - Gaming experience is often limited in scope
  - Programming within a browser has its own unique challenges

Platform: Client/Server/Browser

- Large number of technologies available
  - Adobe Flash: Well established, but gradually being replaced by others
  - HTML 5: Open standard, well supported by the majority of browsers, performance tends to be lacking (especially in 3D)
  - WebGL:
    - Based on OpenGL ES
    - Hardware acceleration: Can handle complex 3D scenes
    - Several libraries build on top of WebGL making it easier to navigate
- Communication Paradigms
  - WebSocket
    - Designed to be implemented in web browsers and servers over TCP
    - Programmed using Go (recommended), Lua, Haskell, etc.
  - Ajax (Asynchronous JavaScript and XML)
    - Load content with JavaScript asynchronously
    - Communicate without waiting

Unity Game Engine

- We will use the Unity game engine throughout the course
  - This includes some of the homework assignments
  - Thus, it is very important that you do not miss the lectures dedicated to getting you up to speed on the Unity Engine!
  - Contact the CAs via email or see the web site to set up your free license
- This Thursday's lecture (Jan 11) will be a Unity boot-camp to get you started
- Then every 2 weeks after that, Thursday's lecture will be dedicated to the Unity engine:
  - Animation (Jan 25), Simulation (Feb 8), Character Animation/Simulation (Feb 22)

Homework 1

- Due Monday the 15th
- Live Demo with the CAs
- Install the Unity Engine, set up a scene/level, and demo it to the CAs
  - import some simple or interesting geometry
  - set up a camera, set up lighting, add textures to your geometry
  - see the web site for more details
- We will get you started via the lecture on Thursday
- 5% of the final grade
- You may work with a partner

Game Design

- 50% of your final grade is directly related to your game
- You may work in teams of 1 to 4 people
- We strongly encourage you to use the Unity Engine
  - since we will have spent 4 lectures teaching you how to use it for your first four homework assignments
  - and we will give you sample game(s)/code working in the engine
- The game must draw heavily on the concepts discussed in the course (talk to the instructor or CAs if you need clarification)
- The last 3 weeks of lecture are dedicated to game development
- Week 8/9: Game Design, Interactivity, and AI
  - Tuesday February 27, Thursday March 1, Tuesday March 6 – typically gaming industry guest lectures – attendance is required and worth 6% of your grade (2% per lecture)
  - HW 5: hand in a list of your team and a description of your proposed game - 4% of final grade
- Week 9 (second lecture): CAs will demo the 2D/3D games that they created, and provide source code

Game Demos

- The completed games will be live-demoed during the regular final exam time slot for the course, and will be 30% of your grade
  - Each person will independently submit a 1 page write-up detailing what they did for the game both individually and in collaboration with others
- You will also be required to give a live in-class demo of what you have so far during the last week of classes
  - Tuesday March 13 or Thursday March 15
  - This counts as 10% of your grade

* The final exam slot is typically used for a game competition. More details later…