CS 354R: Computer Game Technology

http://www.cs.utexas.edu/~theshark/courses/cs354r/
Spring 2016
Instructor and TAs

- **Instructor: Sarah Abraham**
  - theshark@cs.utexas.edu
  - Office: GDC 5.504f
  - Office Hours: MW 3:00-5:00 or by appointment

- **TA**
  - Kaivan Wadia
  - kaivanwadia@gmail.com
  - TBD
  - TBD
Communications

- We’re using Piazza for class communication this semester
  - To enroll go to http://piazza.com/utexas/spring2016/cs354r
  - Once enrolled, your course page is at http://piazza.com/utexas/spring2016/cs354r/home
  - Class announcements will be done via Piazza.
  - Class discussion of issues and questions will be done via Piazza
  - Students should work together to reach understanding before asking for teacher or TA involvement

- Grades and assignments will be done via Canvas, http://canvas.utexas.edu/
  - I won’t be using Canvas for other things, so please look at the webpage and Piazza
The Computer Game Industry

- Hardware makers produce gaming hardware
  - e.g. Sony, Nintendo, Microsoft, …
- Game developers create games
  - e.g. Electronic Arts (EA), Epic, ID, thousands of others
- Publishers publish games
  - e.g. Sony, Nintendo, EA, …
- Similar to books or movies
  - One group creates it, another distributes it, and another supplies the underlying infrastructure
Game Development Team

- Game designers decide on game format and behavior
- Artists design models, textures, animations and otherwise create the look of the game
- Level designers create the game spaces and interactions
- Audio designers are responsible for all sounds
- Programmers write code, to put it all together, and tools, to make everyone else’s job simpler
- And others: production, management, marketing, quality assurance
Course Outline

- Real-time graphics
  - Rendering pipeline review
  - Lighting, shaders, effects
  - Scene graphs and 3D engines
  - Data management

- Game physics
  - Rigid body physics
  - Collision detection
  - Particle systems, fluid dynamics

- Game AI
  - Character behavior
  - Path planning

- Networking
  - Managing delays and bandwidth

- Other aspects of game engines
  - UI, sound, etc.
Take note

- This list and order is tentative, it will surely evolve as the course goes on.
- This is a game technology course, not a game design course. We’re leaving a lot of stuff out.
- New developers at game companies aren’t going to be engine programmers out of the box.
- What are they then?
  - General purpose problem solvers
  - Tool maintainers and possibly tool developers and enhancers
  - Experts at understanding complex software tools they didn’t write
  - Productive in difficult situations
Books

- Recommended “textbook”: “Game Engine Architecture”
  Jason Gregory
  - Good exposition of many issues in the technology and design of game engines
  - Not required but very useful
  - Not nearly as expensive as a textbook

- Other useful books:
  - “Game Programming Gems 1-8”
  - “3D Game Engine Design” David Eberly, lots of equations, less exposition, good math background and computer graphics
  - There are zillions of game books, so pick just one!
  - This stuff is linked from the class webpage

- Website: [www.gamasutra.com](http://www.gamasutra.com)
  - Game developer technical and trade news
  - Other specific web sites
What you should already know

- **3D graphics concepts and programming**
  - “Standard” lighting and shading
  - Modeling techniques
  - Vectors, matrices, geometric reasoning
  - OpenGL will be the graphics API discussed in lectures, but we won’t be working primarily at that level

- **C++ programming**
  - Familiarity with at least one user interface toolkit e.g. FLTK, Glut, Qt, …
    - We may not use any of these, but if you’ve used one, you’ll have an idea what’s happening
  - Scripting language experience a plus, e.g. Lua, Python
  - How to deal when you’re required to use something new, but we don’t teach it to you
Grading and workload

- Projects and reports (no tests)
  - 1 – 2 major projects, broken into smaller pieces, each graded separately
  - Small groups of around 3 assigned by the TA
  - We will allow self-forming groups for the final project
  - Not all projects will be just programming

- Periodic quizzes to check comprehension and attendance
Working in Groups

- Working in groups is not easy, and it is an acquired skill
- It might be the most important thing you learn in here
- For some information on group functioning, read [http://www-honors.ucdavis.edu/vohs/index.html](http://www-honors.ucdavis.edu/vohs/index.html)
- We will assign teams, like in industry, so you don’t get to choose who you work with
- There will be group evaluation exercises throughout the semester to ensure an even distribution of work
  - Continued low performance may result in failing the class
Projects

- The initial project is a ball game

Features:
- Linux, not Windows, is the “release” platform
- You can develop on your own machines, integrate on windows
- Use source code control
- Limited game design: pinball variant
- Limited 3d game, sound, limited UI
- 2d physics
- No animation, not too much object design
- Tools – a big part of this is familiarizing yourself with toolchain

You may add unique features if the project is ahead of schedule
- AI
- More controls
- Game design
Timeline

- Something is due roughly every 2 weeks throughout the semester with weekly milestones
- First stage: basic functionality
- Subsequent stages:
  - 3d camera positioning
  - Physics
  - Sound effects
  - GUI controls
  - Networking
  - AI
- Refinement of earlier stages is allowed
Grading

- Groups will be graded as one, but adjustments will be made based on individual performance.
- Each group will set goals for the stage:
  - Advice will be given on reasonable goals.
  - Goals will be discussed and recorded near the start of each stage.
  - Goals can be modified in the face of problems.
- You will be graded based on how well you achieve your goals with a degree of difficulty factor.
- Each stage will involve turning in some kind of artifact/demo.
Tools

- Your project must run and be turned in on the 64-bit Linux machines in the GDC basement
- We plan to use Ogre3d as the 3d engine
- We’ll recommend sound packages, UI packages, etc. but you can choose your own within limits
- We’ll use Bullet for physics
- You can develop on your own machines, but code and demos are tested on the lab machines
- You will spend a surprising amount of time getting your tools installed, working, and playing together. This is part of the problem solving aspect of this course
- Source code control systems are essential for team projects
Tools for content creation

- Models and art are the biggest expense in real games
  - We try to limit these requirements as much as possible
  - You can use Blender in the lab or on your own machines
  - Use any available tools but provide acknowledgement
  - Assets must be usable in the Linux environment on which your game is delivered but you can develop in non-Linux environments

- Be prepared to write small tools if you think it will make your project easier

- Be prepared to write format converters if you have a good tool that produces output that your game engine can’t input. This is a big deal in the real world as well as in class!
Interactive programming

- Games are user-controlled interactive programs
  - To be effective, they must be responsive to user input in real time, i.e. control must be direct and immediate.
  - Any good interactive program should provide constant, up-to-date feedback about its state.
  - Users must know and understand what is happening at all times.
  - Users must get immediate feedback so they know their input was received.

- Effective interaction is a key component of immersion
  - A game is an alternate reality.
  - Not only must it be visually convincing, it must convince the user that they are in that world by reacting to user behavior as the “real world” would.
Structure of interactive programs

- **Event-driven programming**
  - Everything happens in response to events
  - Events can occur asynchronously with respect to the execution of the program reacting to the event
  - Events can come from users (user control actions) or from system components
  - Events can cause signals or messages to be generated to be sent to a system component. So events, signals, messages are in some sense equivalent
System-generated events

Timer events
- Application calls a function requesting an event at a future time, e.g. next time a frame should be drawn.
- The system provides an event at the requested time.
- Application checks for and responds to the event, e.g. by drawing the next frame.
User generated events

- When you press a button on a joystick, that’s an event
- The joystick hardware sends a signal to the computer called an interrupt
- The OS responds to the interrupt by converting it to an item in an “event queue” for the windowing system
- These events can be kept in priority order, temporal order, etc
- UI toolkits have API elements for checking and responding to events
- There are basically two ways for your software to know an event has happened: ask or be told
Polling vs. waiting

- Most window systems provide a call to check if an event is pending that returns immediately, whether or not there is an event (nonblocking).
- So, if there’s not one, what do you do?
- Loop to keep checking? Go off and do something else for awhile?
- Alternatively, there is also a blocking event function that waits (blocks) until an event has arrived, and only then returns.
- So, what happens while your program waits? Does any work get done? Does the screen freeze up?
Work procedures

- Some systems provide a function to be called when no event is pending
- A blocking event check call executes this function if no event is found, rather than just waiting

Problems?
- Are you sure this would ever be called?
- How long does the function take to execute?
Callbacks

Tell the system what to do when a particular type of event arrives, so the necessary code executes automatically.

Most GUI systems operate this way, through a mechanism of callbacks.

Your application makes a call to the GUI to tell it what function should be executed when a particular kind of event arrives.

- e.g. when a timer event arrives, the system will call a draw function. You make a call ahead of time to give the system a pointer to the draw function you want it to use.
- e.g. when the left mouse button is clicked, the system calls the mouse event function. You provide a pointer to the function you want called to handle mouse events.
Event-response classes

- Two fundamental kinds of event responses:
  - Mode change events
    - Cause the system to shift to a different mode of operation
  - Task events
    - Cause the system to perform a specific task within a mode of operation
- Game software structure reflects this
  - Menu system is separate from game runtime, for instance
Real-time event loops

- Games and similar interactive systems look like an big infinite loop:

```java
while (1) {
    process events
    update state
    render
}
```

- The number of times this loop executes per second is the frame rate (since each render operation creates a new frame).

- Measured in frames per second (fps).
Latency and lag

- Latency is the time it takes from starting to do something to finishing it.
- For user interaction, the latency from when a user provides input to the time they see the response is called lag.
- Controlling lag is extremely important for playability:
  - Too much lag distorts causality.
  - When controlling motion, too much lag can make users motion sick.
  - Too much lag makes it hard to track or target objects.
  - High variance in the amount of lag makes interaction difficult.
Computing lag

Frame time

\{
\text{process input}
\text{update state}
\text{render}
\}

\text{Lag}

\text{Event arrives}

\text{Time}

\begin{align*}
\text{lag}_{\text{max}} & \approx \frac{2}{fr} \\
\text{lag}_{\text{avg}} & \approx \frac{1.5}{fr}
\end{align*}
Reducing lag

- Pick a frame rate = 1/frame time
- Brute force: do as much as you can in a frame time
  - Faster algorithms and hardware means more gets done in that time
  - Budget your resources, everything – graphics, AI, sound, physics, networking, etc. has to be done in the frame time
- Most important to reduce lag between user input and its direct consequences
  - Lag between input and other consequences may matter less
- Update different parts of the game at different rates
  - Achieve this by decoupling separable parts of the game