CS354R

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INTRODUCTION TO GAME ENGINES

WHAT IS GAME TECHNOLOGY?

- Technology that drives games
  - Graphics
  - Physics
  - GUI
  - Networking
  - AI
  - Sound

- Game engine connects these aspects in a coherent, organized manner

WHAT THIS COURSE IS NOT

- **Not** a game design course!
- **Not** a game development class (that's kinda CS354p)
- **Not** an introduction to the basics of C++ (that's CS354p)
- Thus making a game with cool systems is secondary to creating the engine that drives them
- But game features and systems are of course closely connected to engine implementation…

WHAT THIS COURSE IS

- A way to interact with a large-scale software system (specifically a game engine)
- An opportunity to build out common game engine features on top of an existing system
- An exploration of game engine features, their function, and ways to build them
- An environment to master **team-based** development and clear communication

GAME DEVELOPMENT TEAM

- System designers decide on game format and behavior
- Artists create models, textures, and animations
- Level designers create the game spaces and interactions
- Audio designers handle sounds
- Programmers write code to put everything together and create tools to make everyone else's job easier
- And others: production, management, marketing, quality assurance

COMMUNICATIONS

- We'll be using Discord for questions and answers to specific problems, and Discord for class communication/ in-class discussion
- Please join the server so you are able to keep up on issues and ask questions
- Students should work together to solve problems before asking for teacher or TA involvement
- Grades and assignments will be done via Canvas

BOOKS AND RESOURCES

- Recommended "textbook": "Game Engine Architecture" Jason Gregory
  - Good exposition of many engine technology and design
  - Not required but useful
- 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)
- Website: www.gamasutra.com
  - Game developer technical and trade news (articles may be hit or miss)
- GDC Vault and Siggraph archives

CLASS EXPECTATIONS

- During class we'll explore key concepts and provide basic background info for projects
  - Regular in-class quizzes
- Ideally a time for discussion and group exploration
- Outside of class you'll implement this functionality in your game engine
  - Note that this is a **programming-heavy** course!
  - Has a moderately heavy workload according to student reviews
- Throughout the course you will encounter new technology and ideas that I won't teach directly
- This is a "finishing" class to help build job skills in addition to teaching core CS concepts

THINGS I WILL SKIM OVER

- Things I will (mostly) assume you know:
  - 3D graphics concepts and programming
  - Vectors, matrices, geometric reasoning
  - C++ programming
- Things that are nice to know:
  - UI toolkits (FLTK, Glut, Qt, Interface Builder, etc)
  - 3D modeling and texturing (Maya, Substance, ZBrush, etc)
  - Scripting languages (Lua, Python, etc)

GRADING

- Projects and reports (no tests)
- 6 major projects
  - Groups of 3 assigned by the TA for projects 2-4
  - Self-forming groups allowed for the final project
- Regular quizzes to check comprehension but are graded based on attendance

GRADING

- Groups will be graded as one, but adjustments will be made based on individual performance
  - Each group will be evaluated both on the project submissions and in-between milestones **submitted via git**
  - We will use commits to assess how much each group member contributed to the project if there are group conflicts
- For the final project, your team will set its own milestones and goals
  - You will be graded based on how well you achieve these goals factoring in degree of difficulty
- Each milestone will involve turning in a report

WORKING IN GROUPS

- Working in groups is an acquired skill and the most important thing you'll learn in here!
  - For some information on group functioning, read http://www-honors.ucdavis.edu/vohs/index.html
- We assign teams – like in industry
- Group evaluation exercises throughout the semester will ensure an even distribution of work (and grades)
- You must evaluate teammates (even if only to say nice things about them!)
- Low performance and poor team evaluations can result in failing the class

PROJECT FORMAT

- To help with TA grading, your projects should run on the 3rd floor lab machines
  - You **MUST** include
    1. Screen capture of your program in action
    2. A report documenting key features, where they are implemented in the code base, screenshots of your key code, and an explanation of your design decisions
- Godot projects are annoying to download via Canvas, so you **MUST** use version control for submitting your projects
  - We'll use GitLab (www.gitlab.com), so make your repos private
  - You'll branch a "code-freeze" version for each project/milestone and submit repo information via Canvas. **Any modifications to the code-freeze branch after the project deadline will deduct from your late slips**
  - Please include clear documentation on how to build your system even if it's the default instructions (learning to write good documentation is also a skill)

THE ENGINE

- We will be using Godot for our engine development https://godotengine.org/
  - Open source under MIT license
- Godot will be built from source (rather than downloading the binary)
  - We are going to use Godot in the “engine building” way rather than the “game developer” way
  - You will be quite familiar with build systems by the end of this class
- Even if you develop on a personal machine, make sure your project and binaries runs on the lab machines

PROJECT TOOLS

- Source code control systems are essential for team projects
  - Games are asset intensive, so please use **git-lfs** for handling binary data
- Large software systems inevitably require using libraries and build systems
  - Cmake is very common, but Godot uses SCons
  - SCons uses Python 3 so you may need to adjust your environment variables
- If you have concerns about your code building correctly for the TA, please check before the submission deadline

TOOLS FOR CONTENT CREATION

- Models and art are the biggest expense in real games
- This course doesn't require outside art assets, but:
  - You can use Blender in the lab or other programs on your own machines
  - Acknowledge any assets you download/purchase
- Assets must be usable in the Linux environment but you can develop in non-Linux environments
- May need to write format converters if you have a good tool that produces output that you can't input.
  - This is a big deal in the real world!

QUESTIONS ABOUT THE CLASS POLICIES OR ASSIGNMENTS?

INTERACTIVE PROGRAMMING

- A game is a user-controlled program
  - Responsive to user input in real time
  - Provides constant feedback about its state to help users understand what is happening
- Effective interaction is critical for player immersion
  - How do we build software to achieve this?

EVENT-DRIVEN PROGRAMMING

- Everything happens in response to **events**
- Events occur asynchronously with respect to the execution of the program reacting to the event
- Events can come from users or system components
- Generated signals or messages sent to a system component
    - Events, signals, and messages solve similar problems

SYSTEM-GENERATED EVENTS

- Consider: Timer events
  - Application calls a function requesting an event at a future time (e.g. next time a frame should be drawn)
  - System provides this event at the requested time
  - Application checks for and responds to the event (e.g. drawing the next frame)

USER-GENERATED EVENTS

- Consider: Button pressed
  - Controller 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
  - Events can be kept in priority order, temporal order, etc
  - API elements of UI toolkits check and respond to events
- What does it mean to check for events?

POLLING VS. WAITING

- Polling provides a call that returns immediately (non-blocking) to check if an event is pending
  - Happens whether or not there is an event
  - What do you do if there's not one? Loop to keep checking? Go off and do something else?
- Blocking event functions wait (block) until an event has arrived
  - Only returns after the event is processed
  - What happens while your program waits? Does any work get done? Does the screen freeze up?

CALLBACKS

- Tell system what to do when a particular type of event arrives
  - Code is executed automatically when this happens
- Most GUI systems operate this way
- Application makes a call to the GUI telling it what function to execute when the event arrives
  - When a timer event arrives, the system calls a draw function
  - When the left mouse button is clicked, the system calls the mouse event function

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
  - e.g. menu system is separate from game runtime

REAL-TIME EVENT LOOPS

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

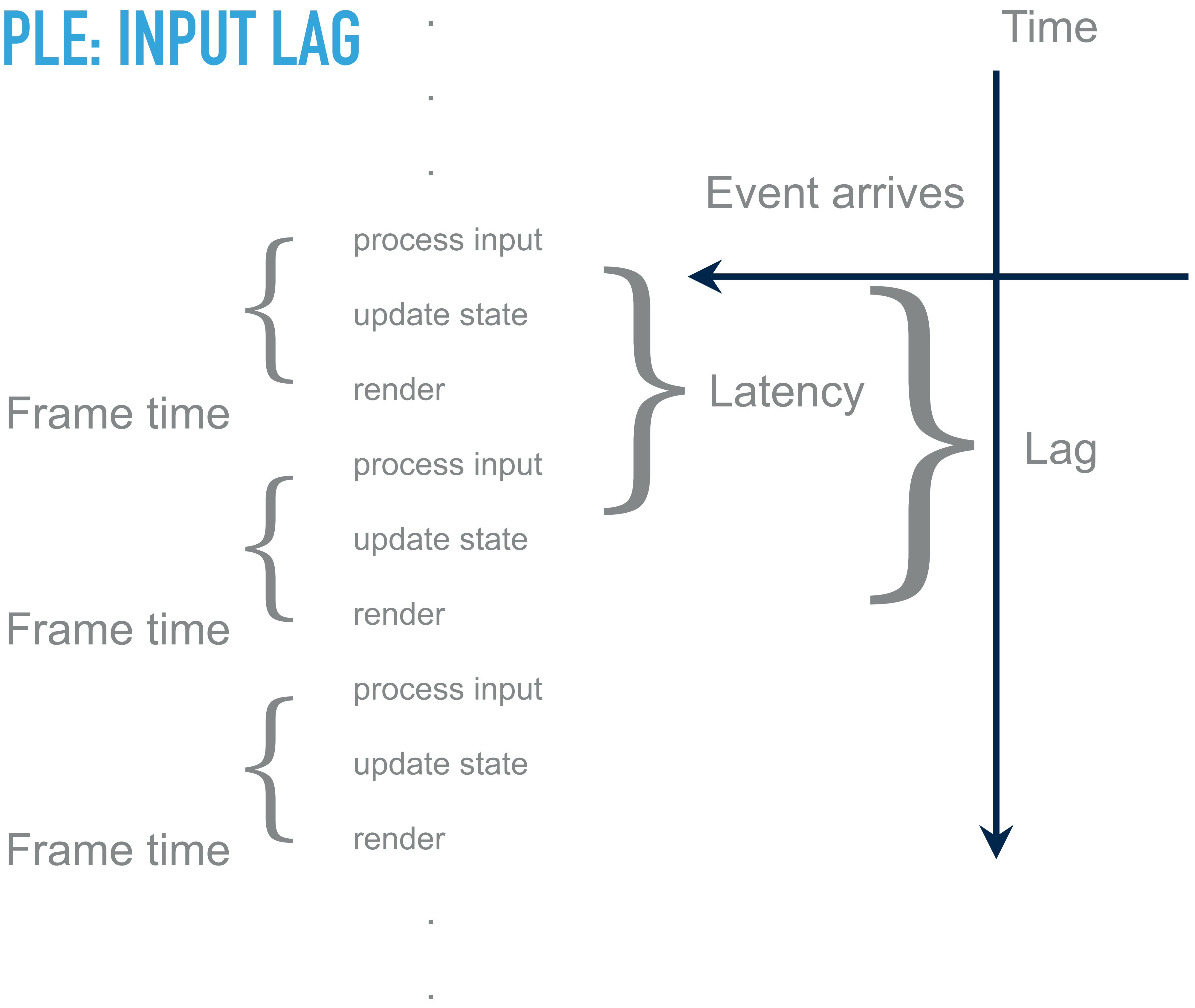
```
while (1) {
    process events
    update state
    render
}
```

- 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
- Lag in user interaction is the latency from when a user provides input to the time they see the response
- Controlling lag is extremely important for playability
  - Distorts causality
  - Causes motion sickness
  - Makes it hard to track or target objects
  - Makes interaction difficult

EXAMPLE: INPUT LAG



BRUTE FORCING LAG

1. Pick a frame rate = 1/frame time
2. Do as much as you can in a frame time

- Faster algorithms and hardware means more can get done!
- Budgeted resources - graphics, AI, sound, physics, networking, etc – must now be done in the frame time
- Is this necessary for all resources?

PRIORITIZING RESOURCES

- Priority is 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
- This is where good software engineering practices come in!
  - Efficient software design, implementation, and algorithms allow for more content/better graphics/deeper immersion, etc!