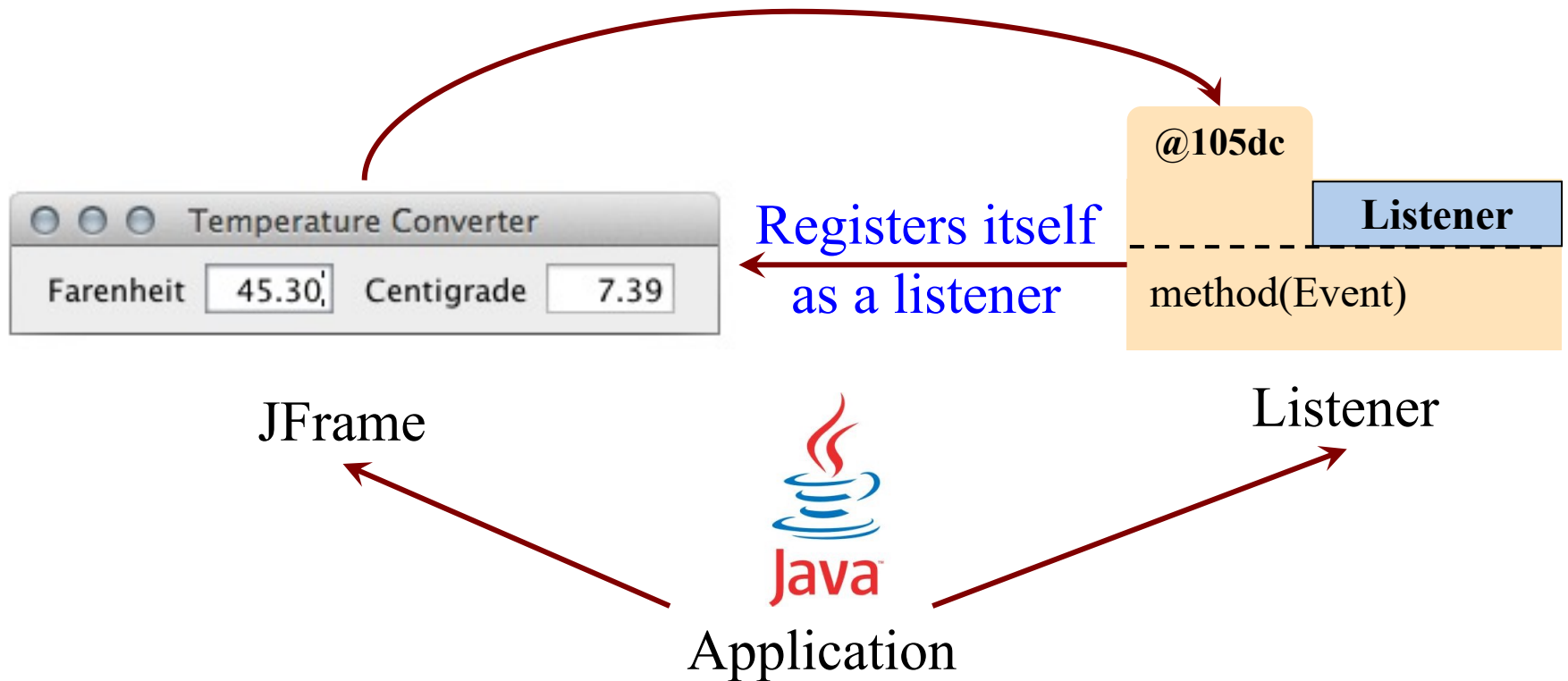


Lecture 9

The Game Loop

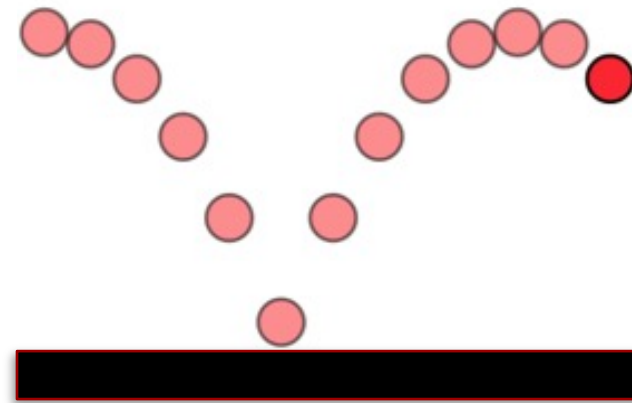
Most Java Apps are Event Driven

Generates event *e* and then
calls `method(e)` on listener

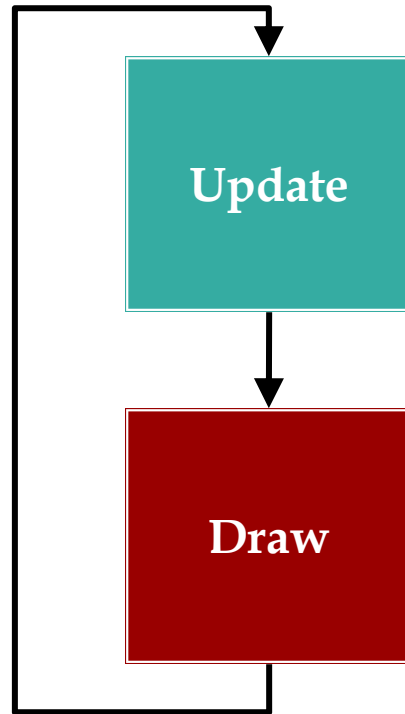


Limitations of the Event Model

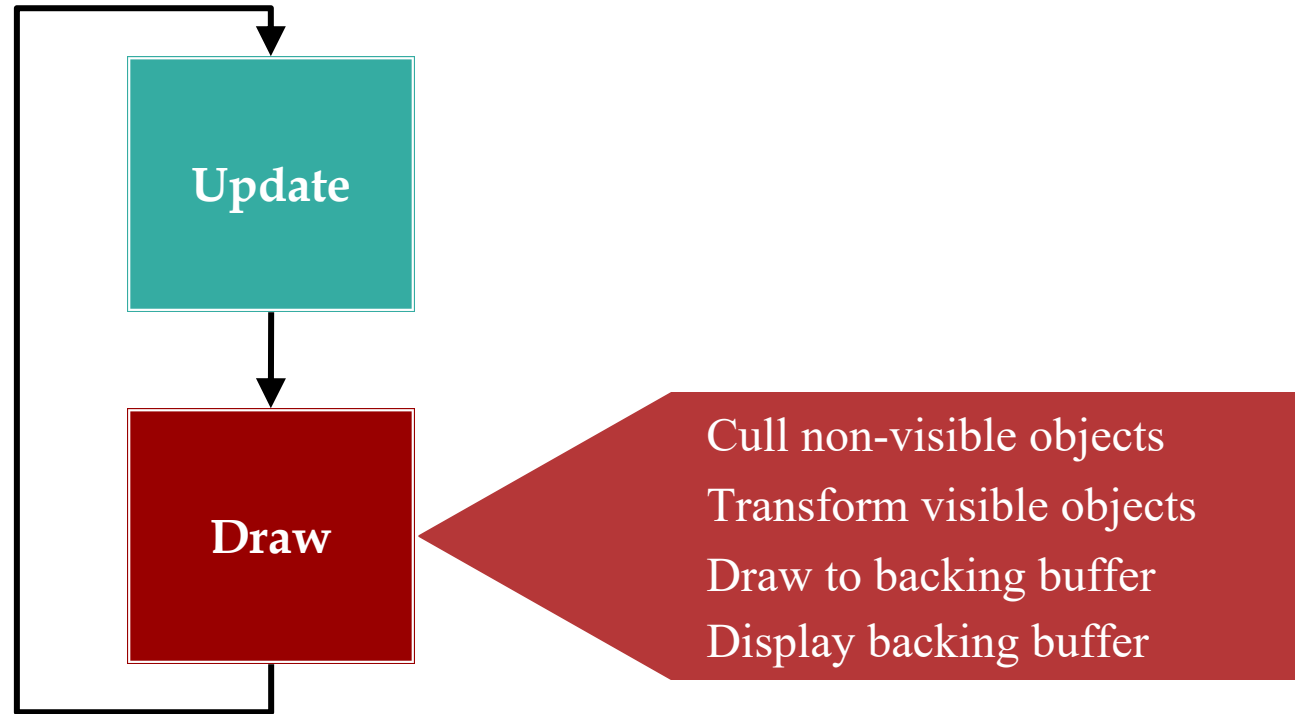
- Program only reacts to user input
 - Nothing changes if user does nothing
 - Desired behavior for productivity apps
- Games continue without input
 - Character animation
 - Clock timers
 - Enemy AI
 - Physics Simulations



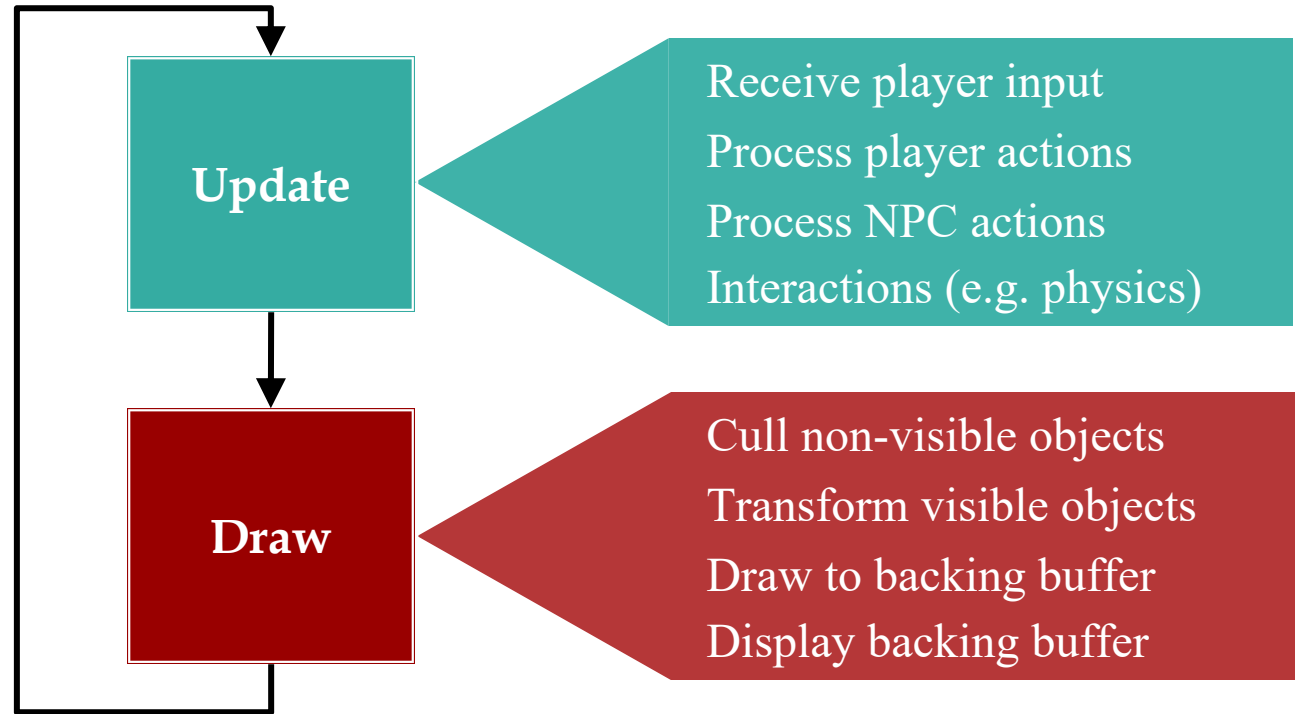
The Game Loop



The Game Loop

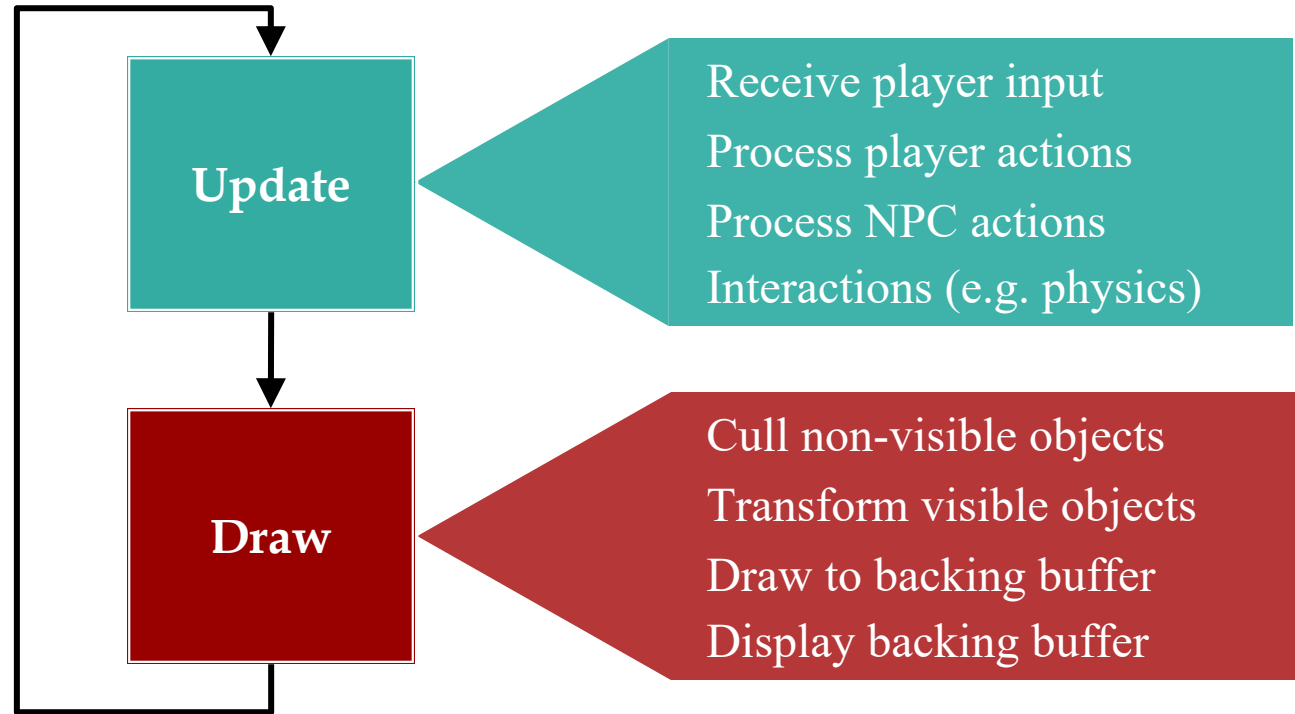


The Game Loop



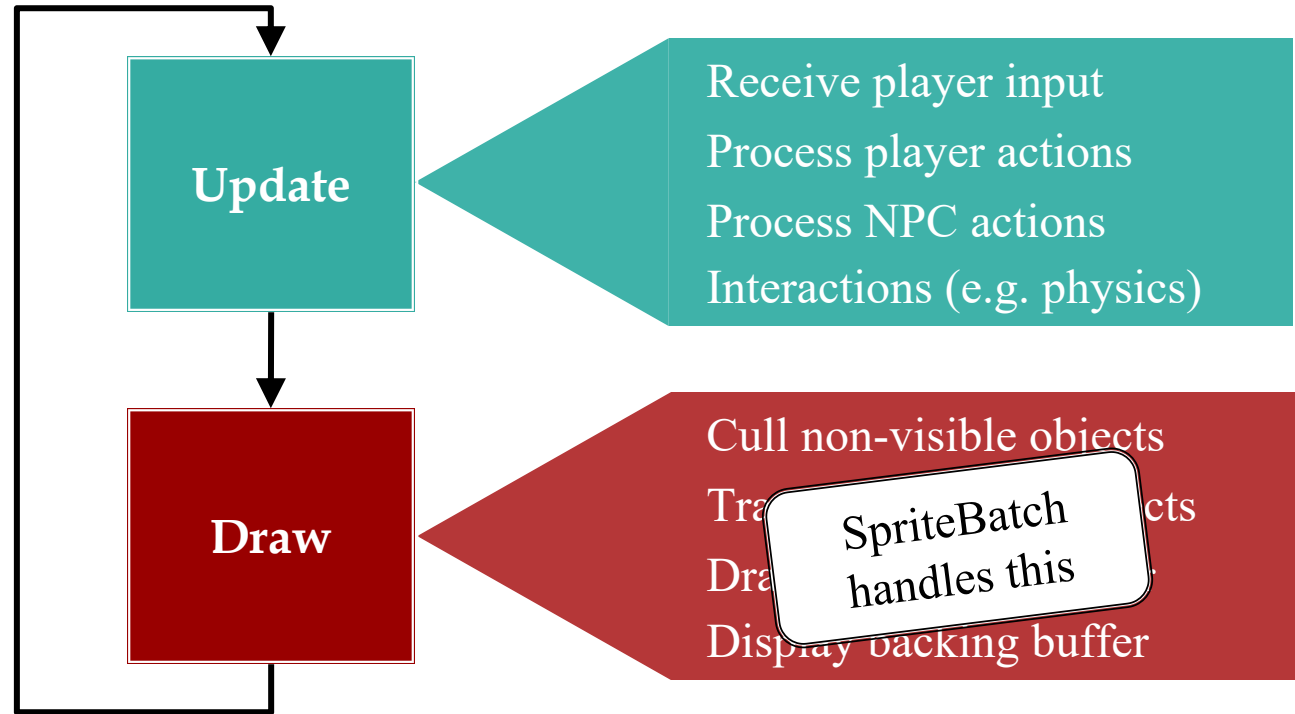
The Game Loop

60 times/s
=
16.7 ms



The Game Loop

60 times/s
=
16.7 ms



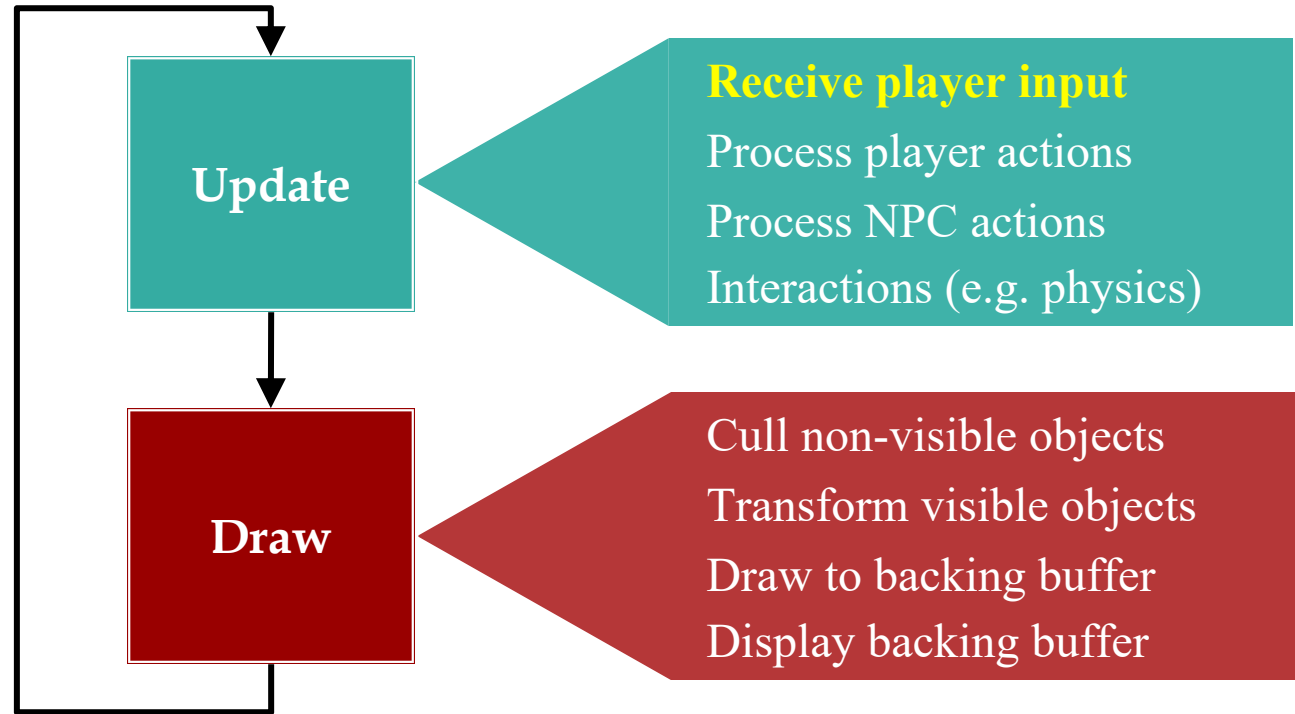
Some Words About the Draw Step

- Graphics cards have their own **memory**
 - Card memory is distinct from RAM
 - Card cannot access RAM directly
- Drawing is **two-step process**
 - Copy data from game state over to GPU
 - Instruct card to draw with this copied data
- **Rule:** do **not** modify game state in draw
 - Will interfere with the copy step
 - Results will not show up on screen

Some Words About the Draw Step



The Game Loop



Player Input

- Traditional input is event-driven
 - Events capture state of controller
 - OS/VM generates events for you
 - Listeners react to events
- Game loop uses **polling** for input
 - Ask for controller state at start of loop
 - **Example**: What is joystick position?
 - If no change, do no actions that loop



Problem with Polling

- Only one event per update loop
 - Multiple events are lost
 - **Example:** Fast typing
- Captures state at beginning
 - Short events are lost
 - **Example:** Fast clicks
- Event-driven does not have these problems
 - Captures **all** events as they **happen**
 - But capture still has a frame-rate **resolution**



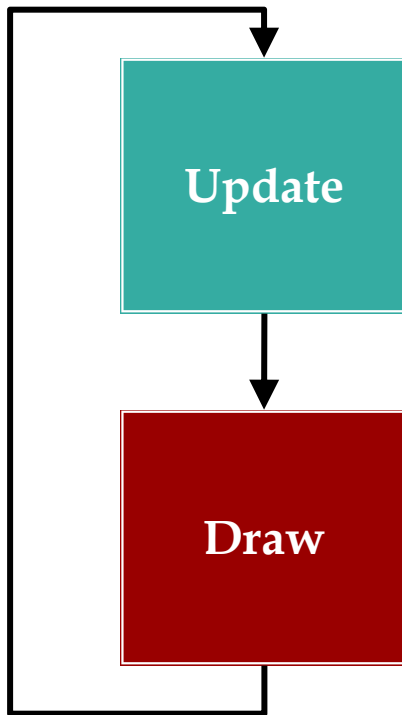
Combining Input Approaches

- LibGDX input is extremely flexible
 - Every input type supports events OR polling
- **Polling:** `Input` interface
 - Access it through the static class `GDX.Input`
 - Allows you to read the input state right now
- **Events:** `InputProcessor` interface
 - Register it with the appropriate input device
 - Works exactly like Swing listeners

Problem: Timing

```
public class MyProcessor implements  
    InputProcessor {
```

```
    public void keyTyped(char c) {  
        // Do something with input
```



How do these
fit together?

```
    }  
}
```

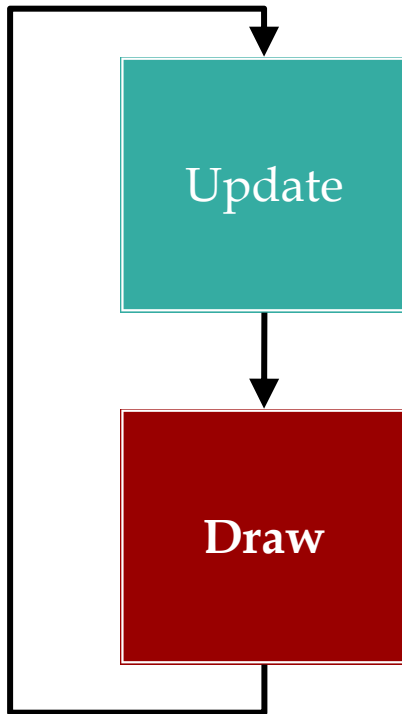
Problem: Timing

```
public class MyProcessor implements  
    InputProcessor {
```

```
    public void keyTyped(char c) {  
        // Do something with input
```

Invocation time
is **unspecified**.

How do these
fit together?



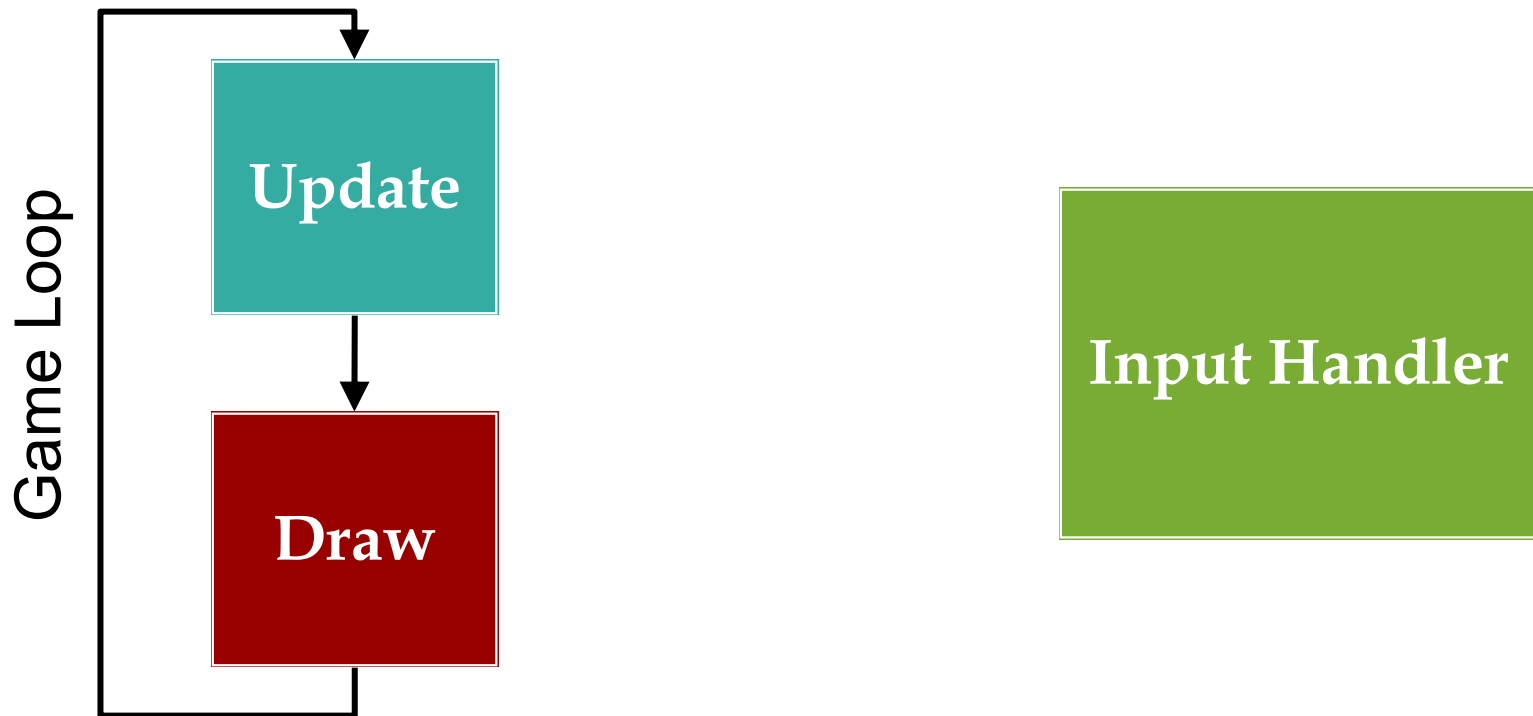
```
}
```

```
}
```


Classic Producer-Consumer Problem

Consumer

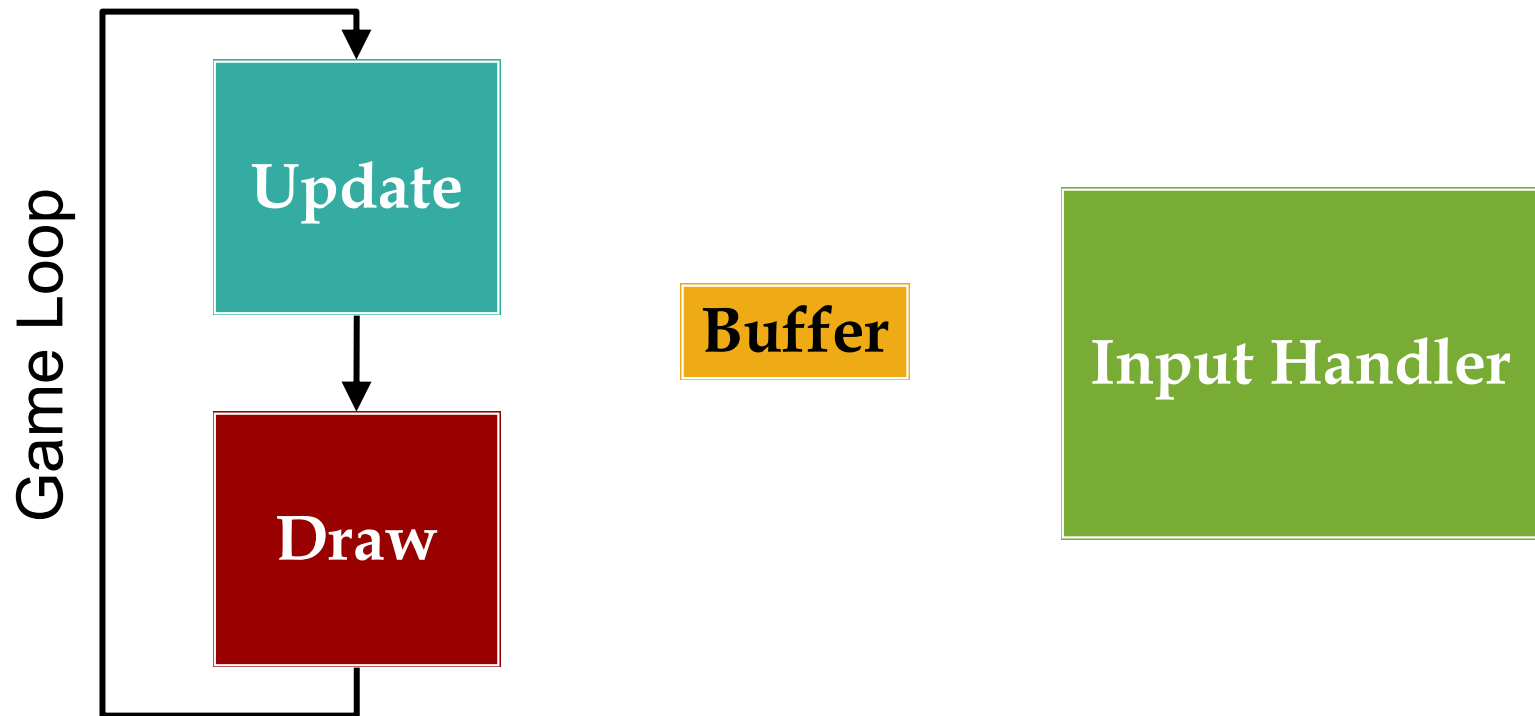
Producer



Classic Producer-Consumer Problem

Consumer

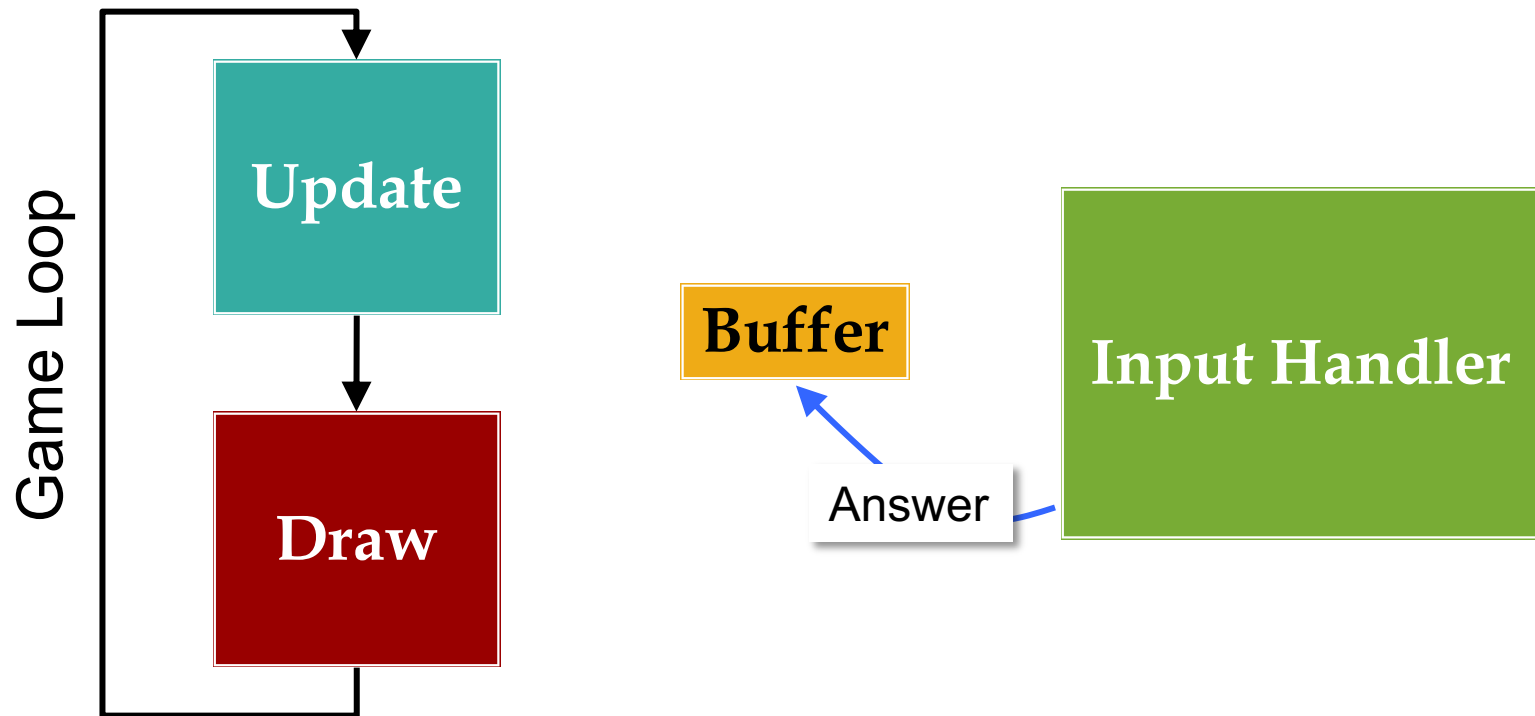
Producer



Classic Producer-Consumer Problem

Consumer

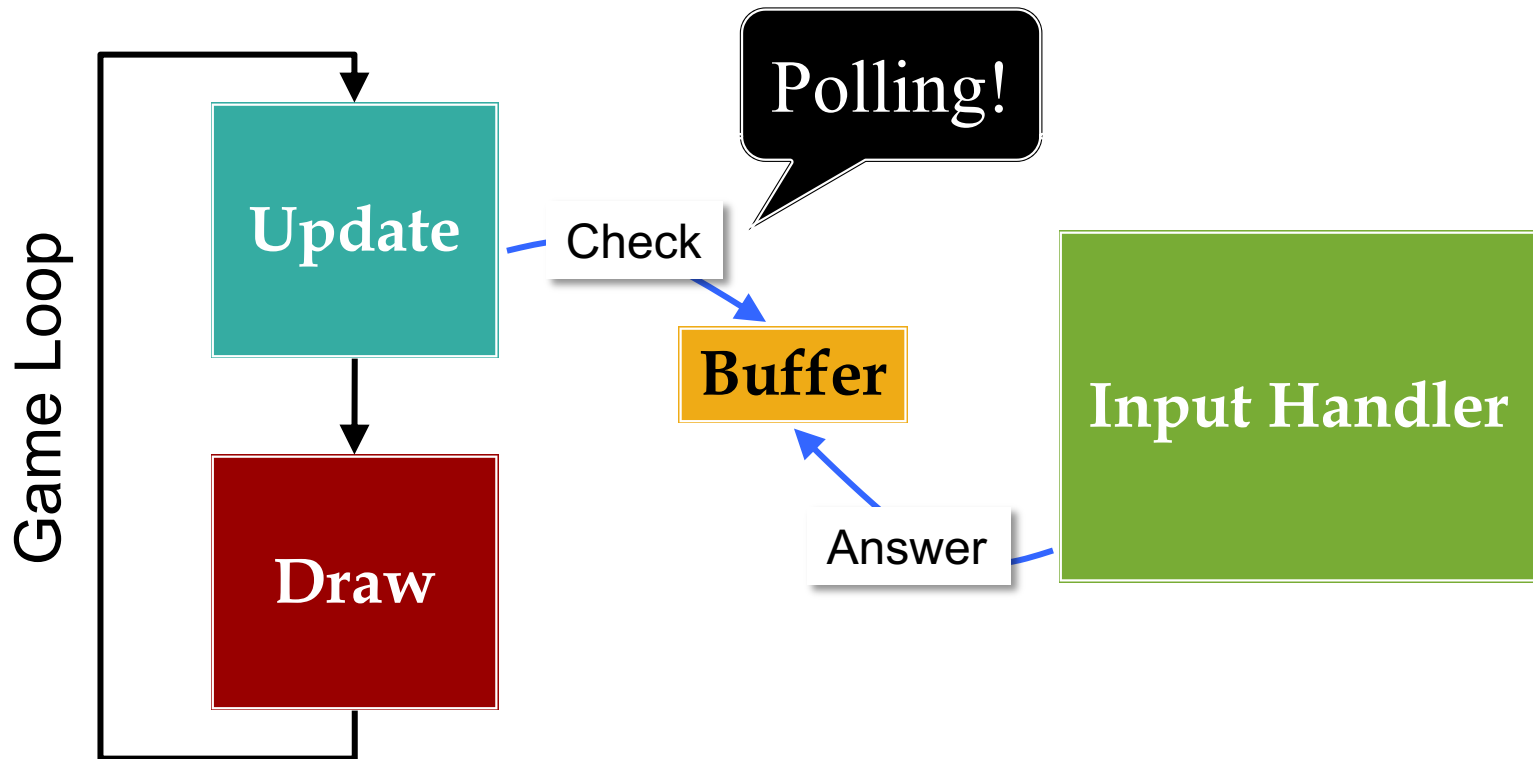
Producer



Classic Producer-Consumer Problem

Consumer

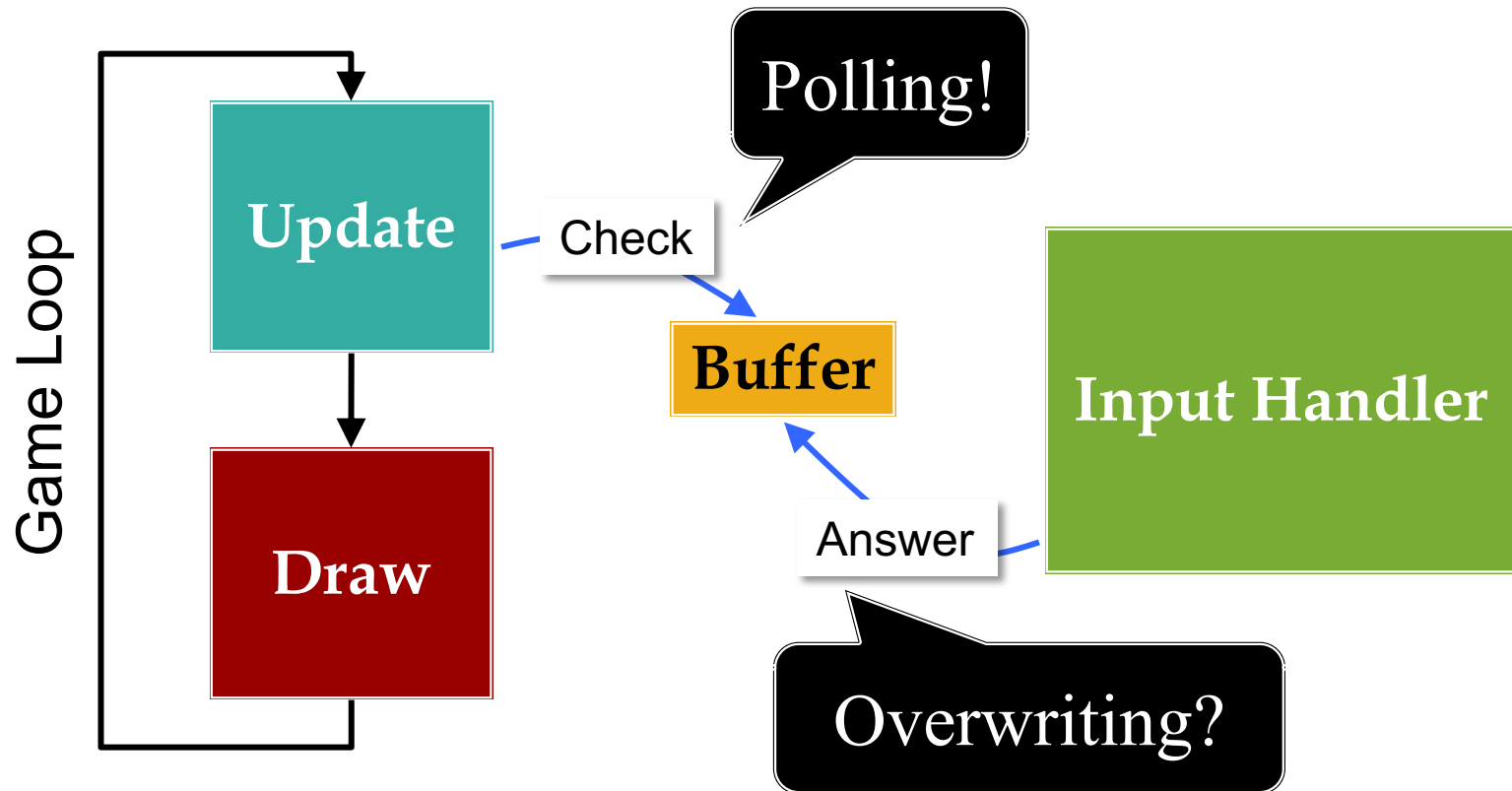
Producer



Classic Producer-Consumer Problem

Consumer

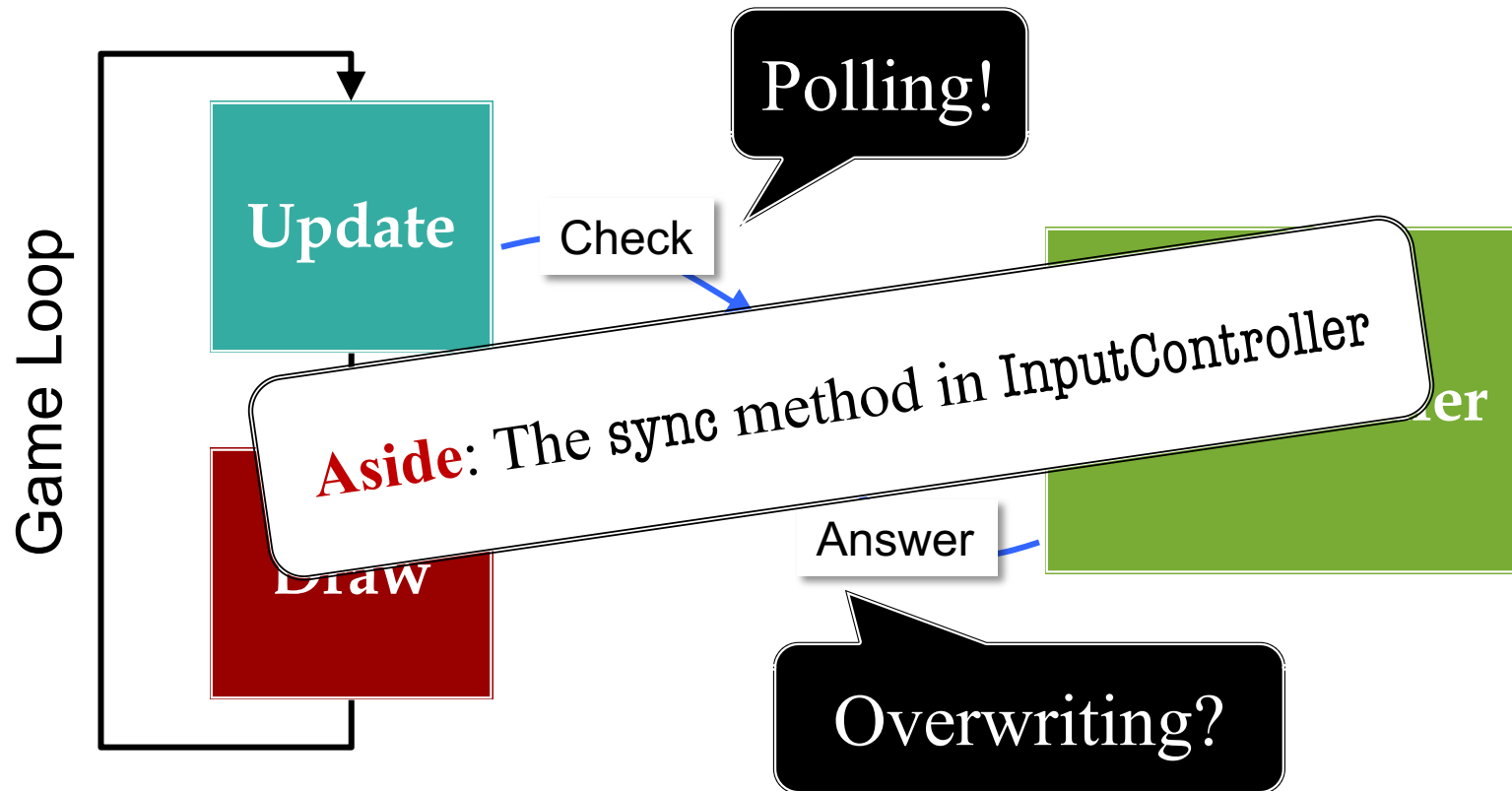
Producer



Classic Producer-Consumer Problem

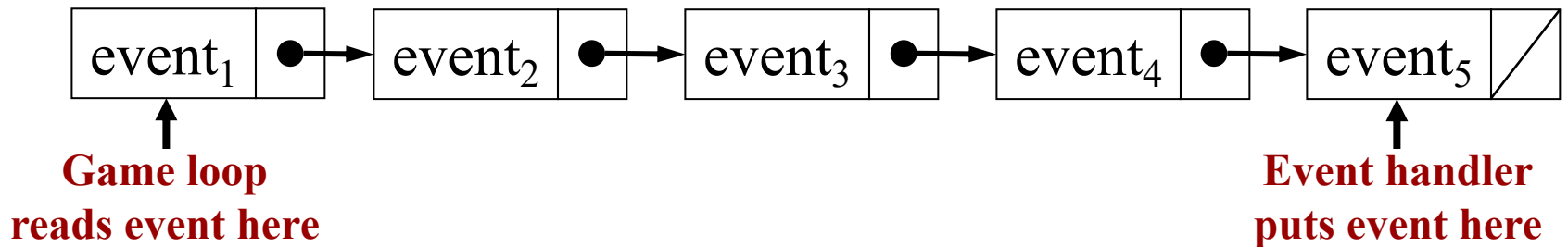
Consumer

Producer



Buffering Input

- If overwriting an issue, need an **event queue**
 - Input processor writes at end of the queue
 - Game loop reads from the front of queue



- Generally requires multiple **threads**
 - Event handler is (usually) OS/VM provided thread
 - Game loop itself is an additional thread

Event Handlers: Really Necessary?

- Most of the time: **No**
 - Frame rate is short: 16.7 ms
 - Most events are > 16.7 ms
 - Event loss not catastrophic
- Buffering is sometimes undesirable
 - Remembers every action ever done
 - But may take a longer time to process
 - If takes too long, just want to abort



Picking the Right Input

Polling

- When game loop is explicit
 - Actively animating screen
 - Must time input correctly
- **Example:** playing the game

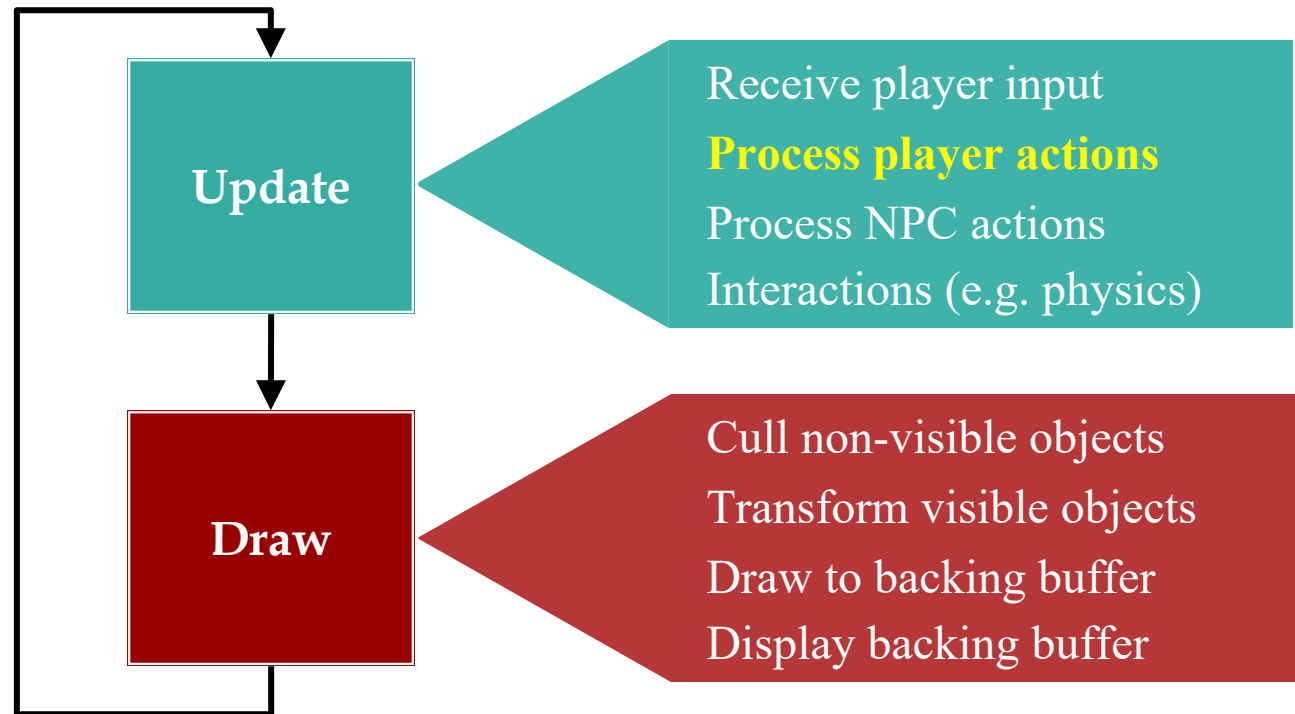


Event Driven

- When game loop is implicit
 - Art assets are largely static
 - Nothing to do if no input
- **Example:** a menu screen



The Game Loop



Player Actions

- Actions alter the game state
 - Can alter player state: **movement**
 - Can alter opponent state: **damage**
- Player actions correspond to user input
 - Choice is determined by input controller
 - Else action is performed by computer
- These are your game **verbs**!

Abstract Actions from Input

- **Actions:** functions that modify game state
 - `move(dx,dy)` modifies `x`, `y` by `dx`, `dy`
 - `attack(o)` attacks opponent `o`
- Input controller **maps** input to actions
 - Read input state from controller
 - Converts to an action, returning the result
- Input handler should never alter state directly!

Abstract Actions from Input

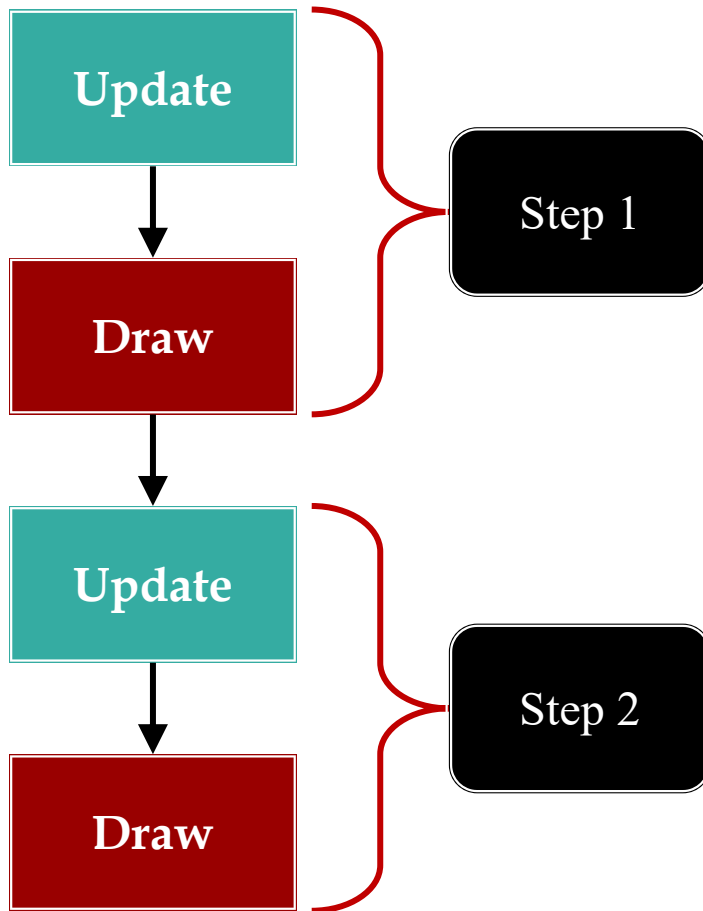
- **Actions:** functions that modify game state
 - move(dx,dy) modifies x, y by dx, dy
 - attack(o) attacks opponent o
- Input controller **maps** input to actions
 - Read input state from controller
 - Converts to an action, returning the result
- Input handler should never alter state directly!
 - Input handler only **identifies the action**

Design versus
Implementation

Actions and Framerate

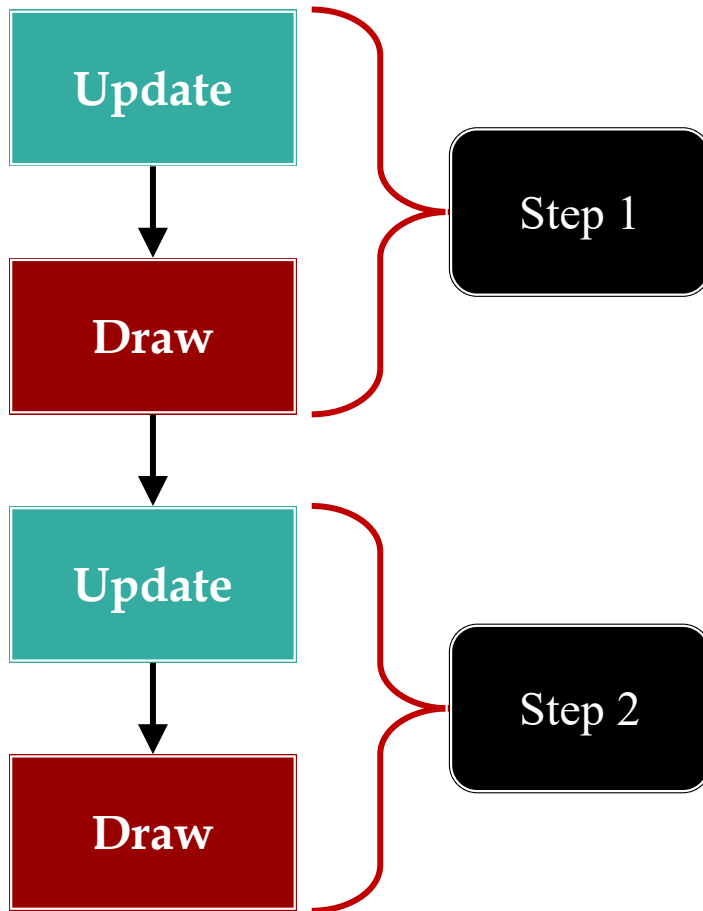
- **Example:** Moving the player on the screen
 - Do we move the same number of pixels each frame?
 - What happens if we go from 60fps to 120fps?
- We get framerate information from dt
 - Parameter indicating how **much time has passed**
 - Multiply this times the movement
 - Now movement is tied to time (seconds), not FPS
- But there is a **problem**...
 - dt is the time since the spent the *last* frame

The Problem with dt



- dt is measured from **step 1**
 - But passed to update at **step 2**
 - Actions are one step *delayed*
- What if **step 2** has different dt?
 - Framerate can have **jitter**
 - Often caused by **vsync**
- **Result:** Jerky movement
- **Solution:** Not in this course
 - Will assume dt “constant”
 - Take 4152 for more

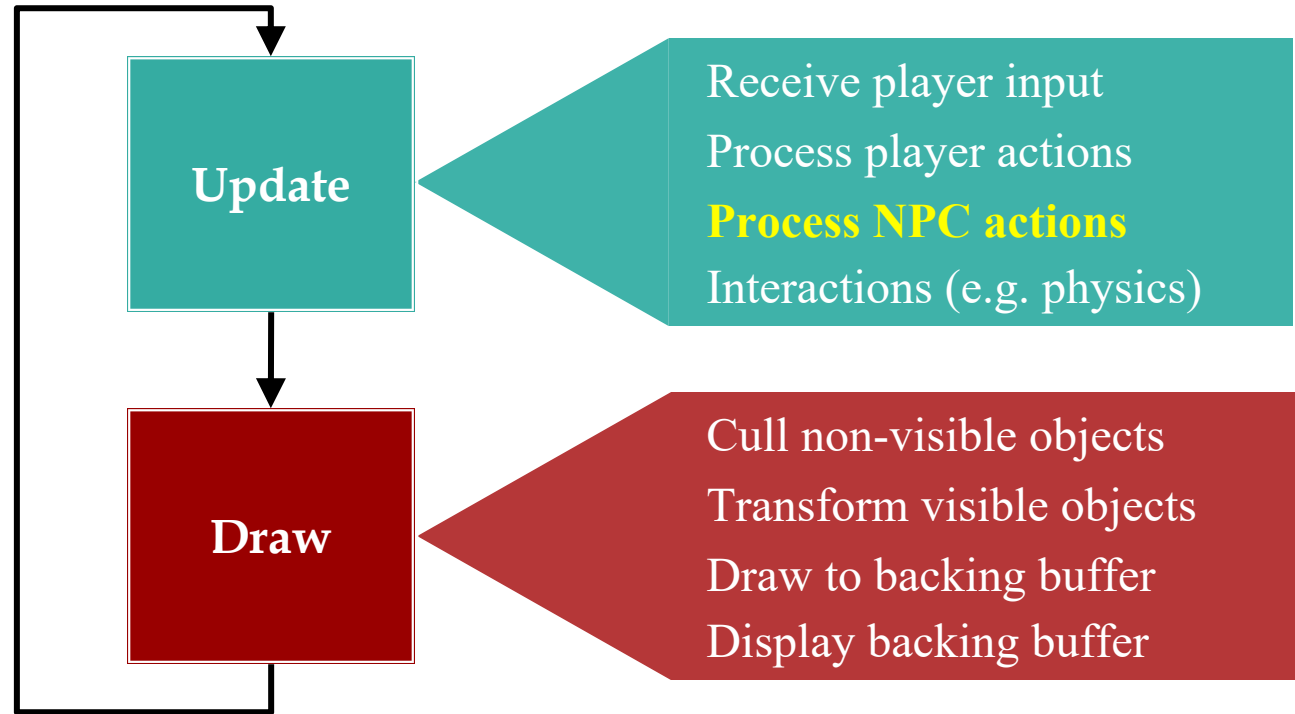
The Problem with dt



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 - Actions are one step *delayed*
- What if **step 2** has different dt?
 - Framerate can have **jitter**
 - Often caused by **vsync**
- **Result:** Jerky movement
- **Solution:**

But see video linked
on course page

The Game Loop



NPC: Non-Player Character

- NPC is an intelligent computer-controlled entity
 - Unlike a physics object, it can act, not just interact
 - Sometimes called an *agent*
- NPCs have their own actions/verbs
 - But no input controller to choose
- Work on **sense-think-act** cycle
 - **Sense:** perceive the world around it
 - **Think:** choose an action to perform
 - **Act:** update the game state



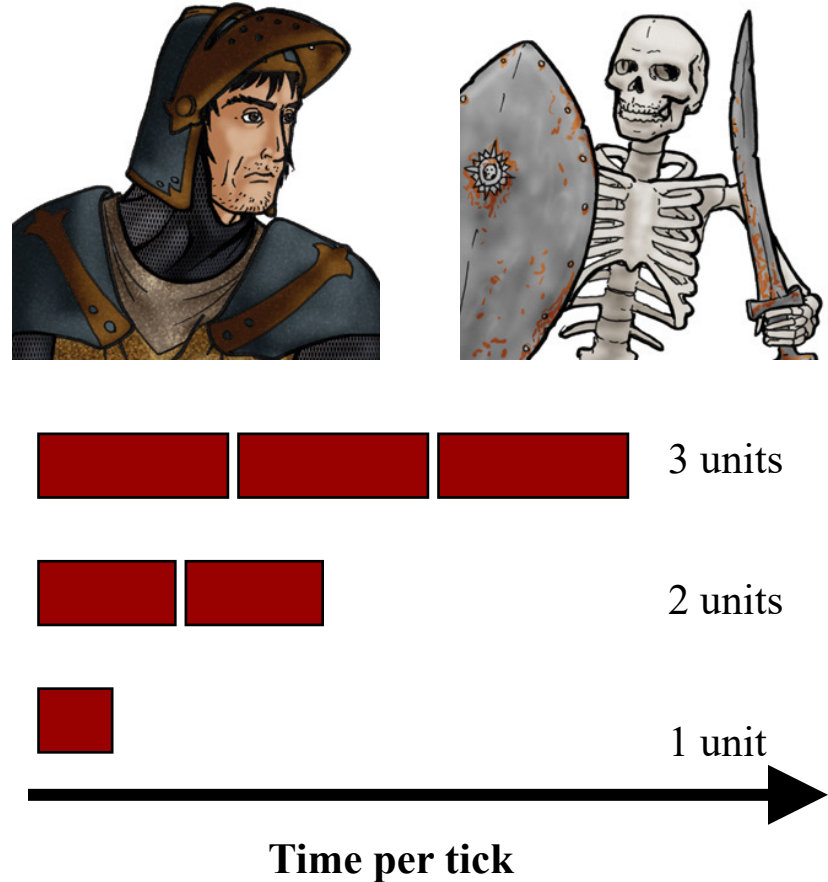
Act versus Sense-Think

- Act should be *very* fast!
 - Function to update state
 - **Example**: apply velocity
 - Exactly like the player
- Sense-think unique to NPC
 - The *hard* computation
 - Focus of AI lectures
- **Multiplayer**: Replace sense-think with human decision



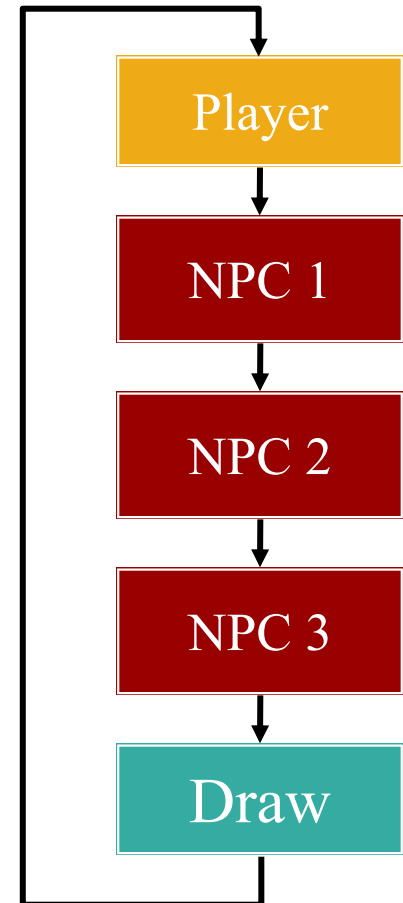
Problem with Sensing

- Sensing may be slow!
 - Consider *all* objects
- Example: morale
 - n knights, n skeletons
 - Knights fear skeletons
 - Proportional to # seen
- Count skeletons in view
 - $O(n)$ to count skeletons
 - $O(n^2)$ for all units



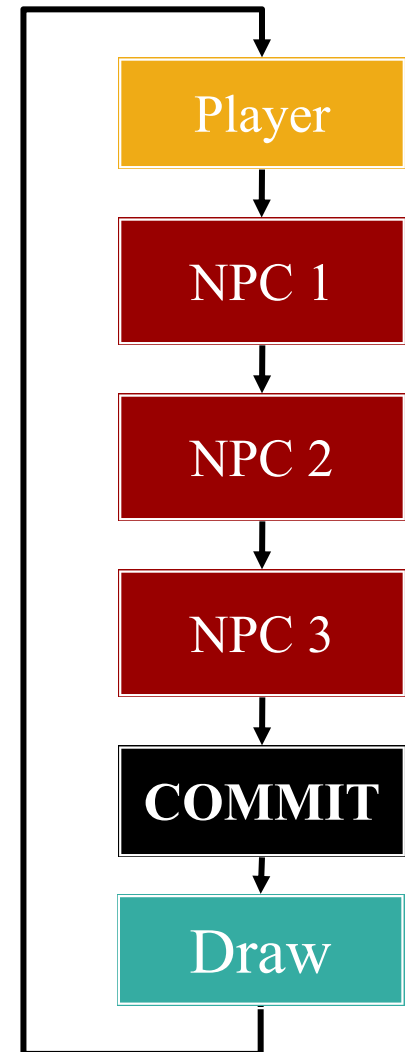
Processing NPCs

- Naïve solution: **sequentially**
- **Problem:** NPCs react too fast!
 - Each reads the actions of previous
 - Even before drawn on screen!

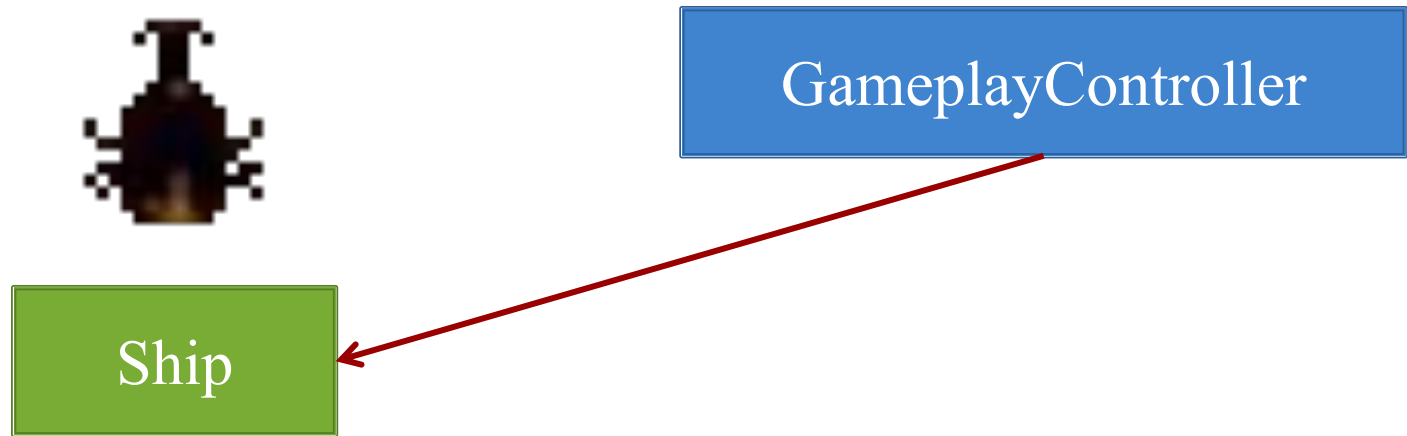


Processing NPCs

- Naïve solution: **sequentially**
- **Problem:** NPCs react too fast!
 - Each reads the actions of previous
 - Even before drawn on screen!
- **Idea:** only react to what can see
 - *Choose* actions, but don't perform
 - Once all chosen, then perform
 - Another reason to abstract actions



Processing Actions in Lab 3



- Decides whether to shoot
- Stores intent in the object
- But **DOES NOT** shoot
- Waits until objects commit
- Checks intent in Ship object
- Performs action for intent

Problem: Pathfinding

- Focus of Game Lab 2
 - Crucial if top view
 - Major area of research
- Potentially very slow
 - n NPCs, g grid squares
 - Dijkstra: $O(g^2)$
 - For each NPC: $O/ng^2)$
- **Moving obstacles?**

7	6	5	6	7	8	9	10	11		19	20	21	22
6	5	4	5	6	7	8	9	10		18	19	20	21
5	4	3	4	5	6	7	8	9		17	18	19	20
4	3	2	3	4	5	6	7	8		16	17	18	19
3	2	1	2	3	4	5	6	7		15	16	17	18
2	1	0	1	2	3	4	5	6		14	15	16	17
3	2	1	2	3	4	5	6	7		13	14	15	16
4	3	2	3	4	5	6	7	8		12	13	14	15
5	4	3	4	5	6	7	8	9	10	11	12	13	14
6	5	4	5	6	7	8	9	10	11	12	13	14	15

Problem: Pathfinding

- Focus of Game Lab 2
 - Crucial if top view
 - Major area of research

- Potentially very slow

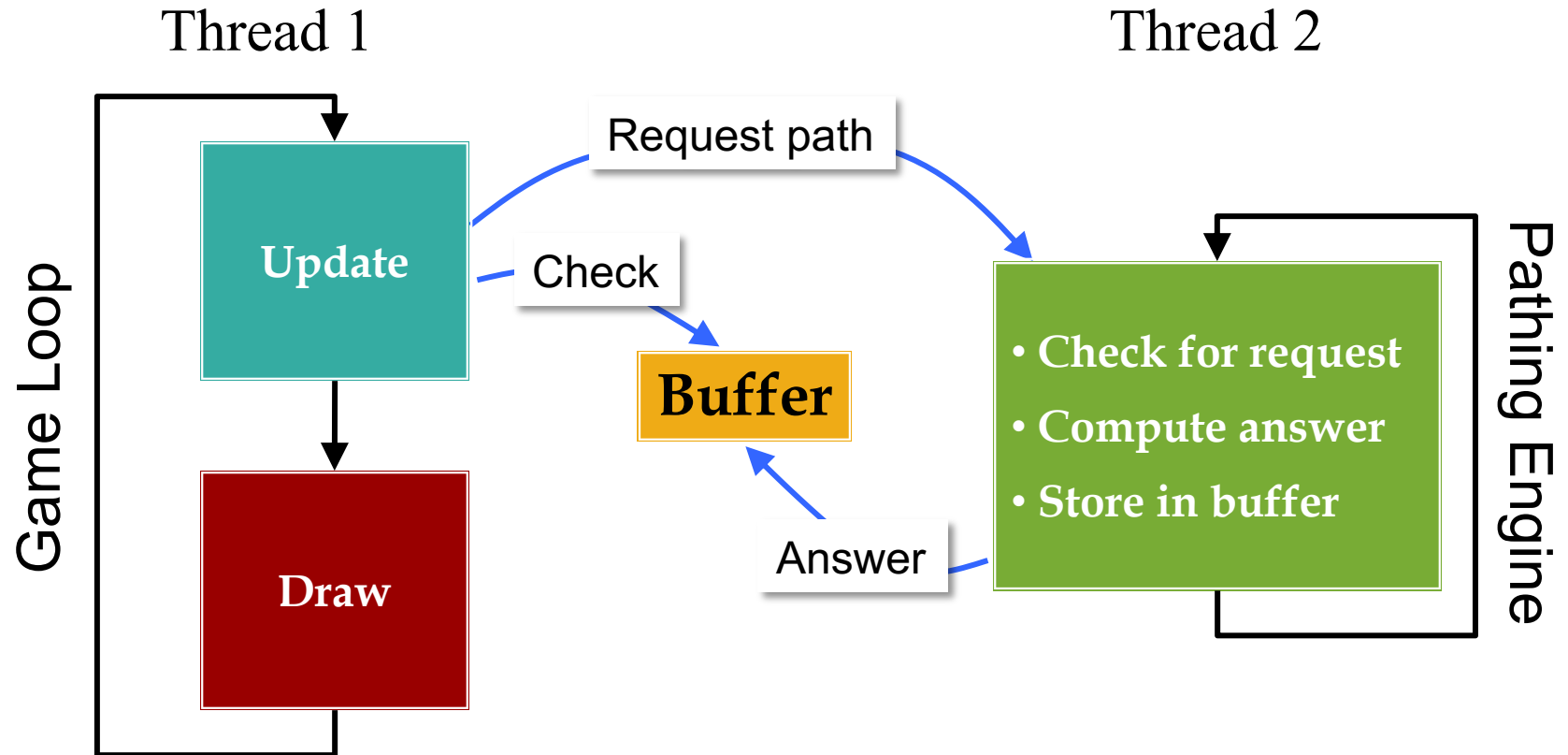
Often more than 16.7ms

- For each NPC: $O(n^2)$

- **Moving obstacles?**

7	6	5	6	7	8	9	10	11		19	20	21	22
6	5	4	5	6	7	8	9	10		18	19	20	21
5	4	3	4	5	6	7	8	9		17	18	19	20
4	3	2	3	4	5	6	7	8		16	17	18	19
3	2	1	2	3	4	5	6	7		15	16	17	18
2	1	0	1	2	3	4	5	6		14	15	16	17
1	0	-1	0	1	2	3	4	5		13	14	15	16
0	-1	-2	-1	0	1	2	3	4		12	13	14	15
-1	-2	-3	-2	-1	0	1	2	3		11	12	13	14
-2	-3	-4	-3	-2	-1	0	1	2		10	11	12	13
-3	-4	-5	-4	-3	-2	-1	0	1		9	10	11	12
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-6	-7	-8	-7	-6	-5	-4	-3	-2		6	7	8	9
-7	-8	-9	-8	-7	-6	-5	-4	-3		5	6	7	8
-8	-9	-10	-9	-8	-7	-6	-5	-4		4	5	6	7
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-10	-11	-12	-11	-10	-9	-8	-7	-6		2	3	4	5
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-20	-21	-22	-21	-20	-19	-18	-17	-16		-8	-7	-6	-5
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-47	-48	-49	-48	-47	-46	-45	-44	-43		-35	-34	-33	-32
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-80	-81	-82	-81	-80	-79	-78	-77	-76		-68	-67	-66	-65
-81	-82	-83	-82	-81	-80	-79	-78	-77		-69	-68	-67	-66
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-83	-84	-85	-84	-83	-82	-81	-80	-79		-71	-70	-69	-68
-84	-85	-86	-85	-84	-83	-82	-81	-80		-72	-71	-70	-69
-85	-86	-87	-86	-85	-84	-83	-82	-81		-73	-72	-71	-70
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Asynchronous Pathfinding



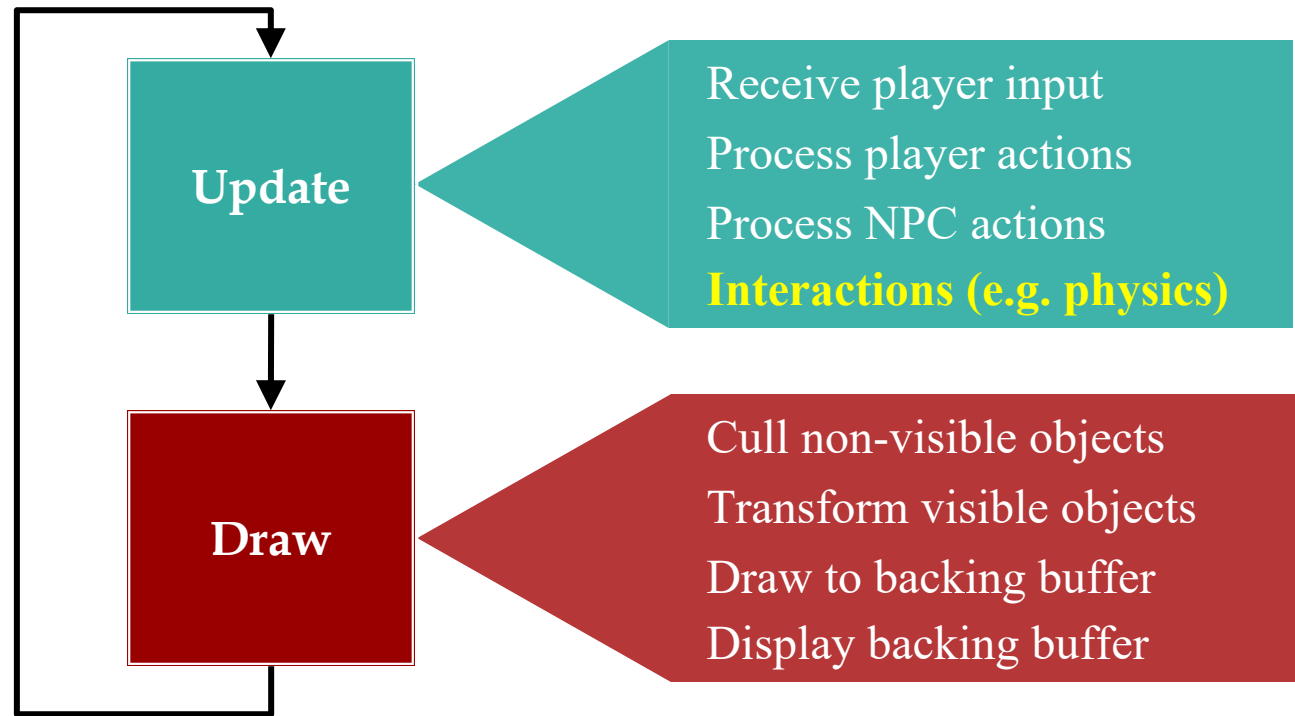
Looks like input buffering!

Asynchronous Pathfinding

- NPCs do not get answer right away
 - Check every loop until answered
 - Remember request; do not ask again
- What to do until then?
 - Act, but don't think!
 - If nothing, **fake** something
 - “Stomping Feet” in RTSs



The Game Loop



Purpose of a Physics Engine

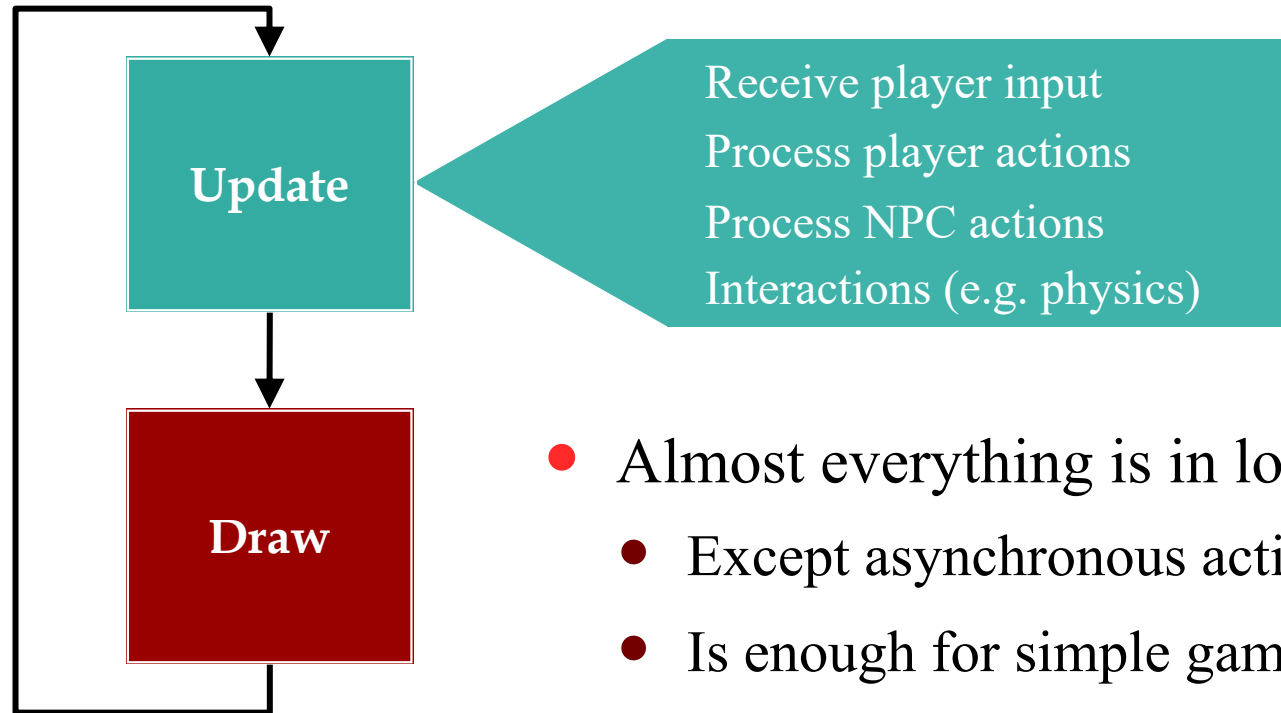
- Moving objects about the screen
 - **Kinematics**: Without regard to external forces
 - **Dynamics**: The effect of forces on the screen
- Collisions between objects
 - **Collision detection**: Did a collision occur?
 - **Collision resolution**: What do we do?
- More on this issue later (~Spring Break)

Physics Engines: Two Levels

- **White Box:** Engine corrects movement errors
 - Update object state ignoring physics
 - Physics engine nudges object until okay
- **Black Box:** Engine handles everything
 - Do not move objects or update state
 - Give forces, mass, velocities, etc. to engine
 - Engine updates to state that is *close enough*

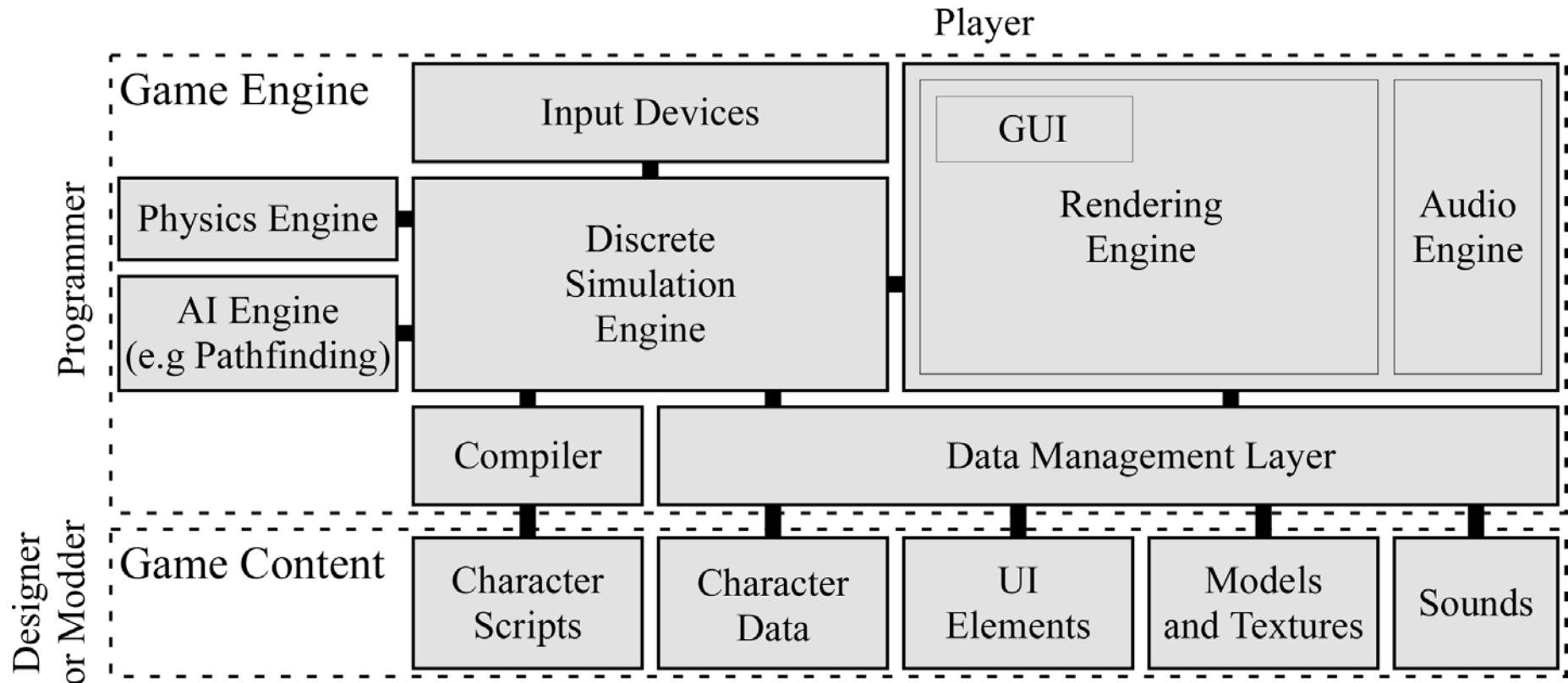


The Game Loop

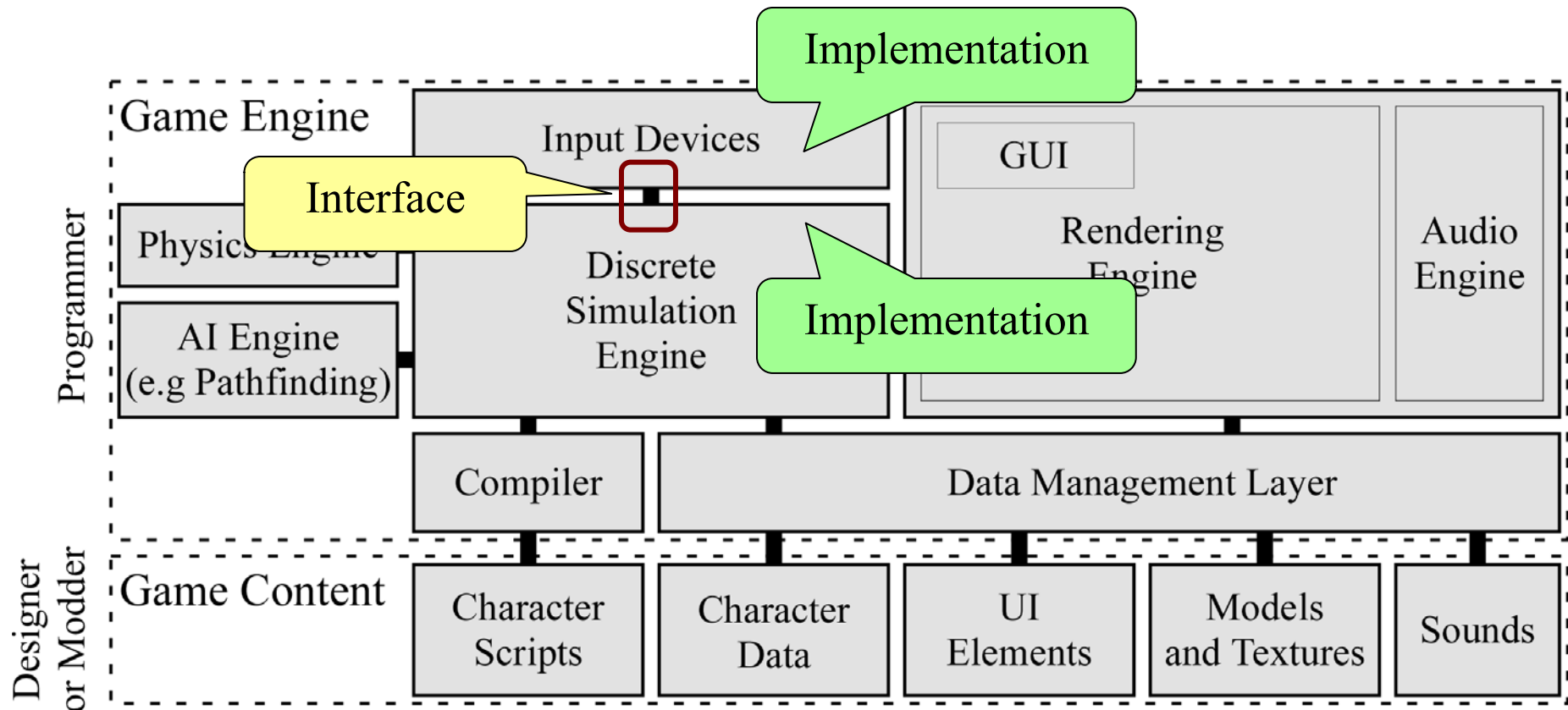


- Almost everything is in loop
 - Except asynchronous actions
 - Is enough for simple games
- How do we organize this loop?
 - Do not want spaghetti code
 - Distribute over programmers

Architecture: Organizing Your Code



Architecture: Organizing Your Code



Where Did This Come From?

