COMP150: Game Development Practices

The main loop

Basic game architecture

- CPUs execute sequences of instructions
  - At the CPU level, there is no such thing as "when *X* happens, do *Y*"
  - Instead: "keep checking whether *X* has happened; if so, do *Y*"
- Thus games need to have a **main loop**
- The main loop is usually part of the game's **engine**
  - Engines and high level frameworks (e.g. Kivy, Unity, Unreal) usually implement the main loop for you
  - Low level frameworks (e.g. SDL, OpenGL, DirectX) usually require you to implement your own main loop

The basic main loop

The most basic main game loop does **three** things:

1. Handle **input**
   - Mouse, keyboard, joypad etc.
   - Operating system events (minimise, close, alt+tab etc.)
2. **Update** the state of the game
   - Physics, collision detection, AI etc.
3. **Render** the game to the screen

It does these **once per frame** (typically 30 or 60 times per second)

The basic main loop

```
bool running = true;

while (running)
{
    handleInput();
    update();
    render();
}
```

Handling input

There are two ways of handling input in a game:

- By handling events
  - `SDL_PollEvent`
  - See `https://wiki.libsdl.org/SDL_EventType` for a list of event types
- By querying state
  - `SDL_GetKeyboardState`, `SDL_GetMouseState`, `SDL_GameControllerGetAxis`, etc.

What's the difference?

- Event: "The space bar was (pressed / released)"
- State: "The space bar is (down / up) right now"

Updating the game state

- Generally this is where your **game logic** is implemented
- I.e. anything not directly related to input or graphics
- What goes in here depends on the game...

Rendering

- This is where you draw the **current state of the game** to the screen
- Also draw any **heads-up display (HUD)** elements, e.g. score, lives, mini-map, etc.
- Graphical effects (animations, particles) may be handled **either** in the render step **or** in the update step (but be consistent)
- In frameworks like SDL, you generally **redraw everything** on every frame
- Rendering in SDL is **double buffered**
  - `SDL_Render*` actually draws to an **off-screen buffer**
  - `SDL_RenderPresent` displays the off-screen buffer on screen

Screen refresh rate

- Old CRT monitors worked by scanning an electron beam down the screen
  - `https://www.youtube.com/watch?v=lRidfW_l4vs`
- Hence the term **(vertical) refresh rate**
- Refresh rate is measured in **cycles per second** i.e. **Hz**
- Other monitor technologies work differently, but still refresh the screen at regular intervals

Frame rate

- We generally want to sync it up so that **one display refresh = one main loop iteration**
- If the main loop runs too slowly, we get "lag"
- If the main loop runs too quickly, we waste resources on drawing things faster than the display can show them

Limiting the frame rate

- If the renderer was created with the `SDL_RENDERER_PRESENTVSYNC` flag, `SDL_RenderPresent` waits for the next vertical blank
- This limits the game's frame rate to the refresh rate of the device
- However, refresh rates can vary
  - Older TVs: $\sim$ 30Hz
  - HDTVs and standard monitors: 60Hz
  - High-end "gaming" monitors: 120Hz or higher

Limiting the update rate

- Having the update frequency depend on the refresh rate would be bad!
  - The game could appear to run in slow or fast motion, completely changing the gameplay
- This was the situation on older consoles: American/Japanese versions of games actually ran a little faster than European versions, due to the NTSC TV standard having a higher refresh rate than PAL!

Variable time step

- Have the update step depend on the **elapsed time since the last update**
- Also known as the **delta time**
- E.g. instead of this:

```
player.positionX += player.velocityX;
```

- do this:

```
player.positionX += player.velocityX * deltaTime;
```

Measuring elapsed time

```
bool running = true;
Uint32 lastFrameTime = SDL_GetTicks();

while (running)
{
    Uint32 currentTime = SDL_GetTicks();
    Uint32 deltaTime = currentTime - lastFrameTime;
    // deltaTime is the number of milliseconds since ↩
        the last update

    handleInput();
    update(deltaTime);
    render();

    lastFrameTime = currentTime;
}
```

Variable time step

- **Good:** the game will no longer run in slow or fast motion at different refresh rates
- **Bad:** may increase the complexity of the `update` function
- **Bad:** some systems (e.g. physics) may become prone to numerical errors

Fixed time step

- Perform the update at a **fixed rate**, e.g. 60 times per second
- If refresh rate $<$ 60Hz, update several times per frame
- If refresh rate $>$ 60Hz, update once every few frames

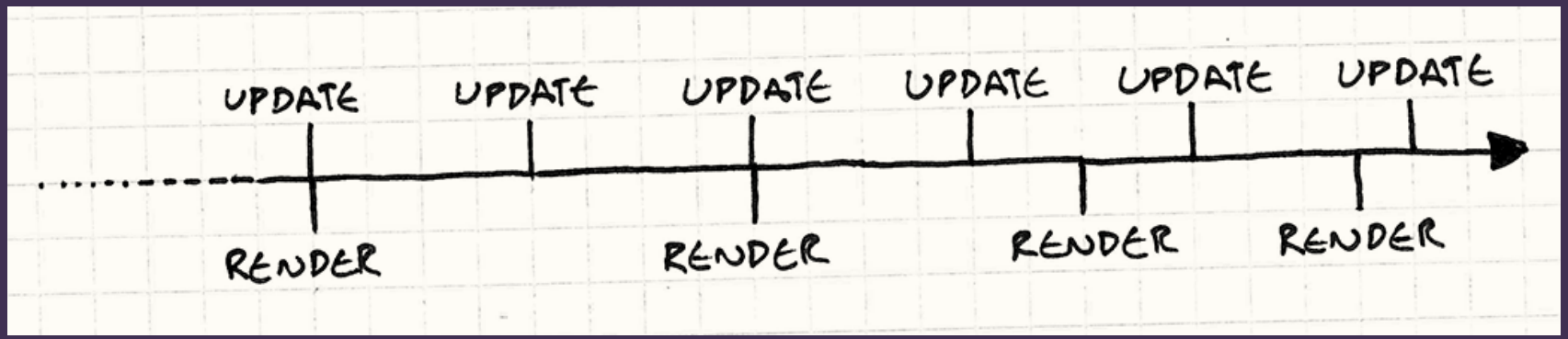
Fixed time step

```
bool running = true;
Uint32 lastUpdateTime = SDL_GetTicks();
const Uint32 timePerUpdate = 1000 / 60;

while (running)
{
    Uint32 currentTime = SDL_GetTicks();
    handleInput();

    while (currentTime - lastUpdateTime >=
        timePerUpdate)
    {
        update();
        lastUpdateTime += timePerUpdate;
    }

    render();
}
```

Stalling

- What if `update` takes longer than `timePerUpdate` to execute?
- The `while` loop will perform more and more iterations in an effort to catch up, eventually grinding the game to a halt
- **Solution:** `break` out of the loop after a maximum number of iterations (e.g. 10)

Interpolation

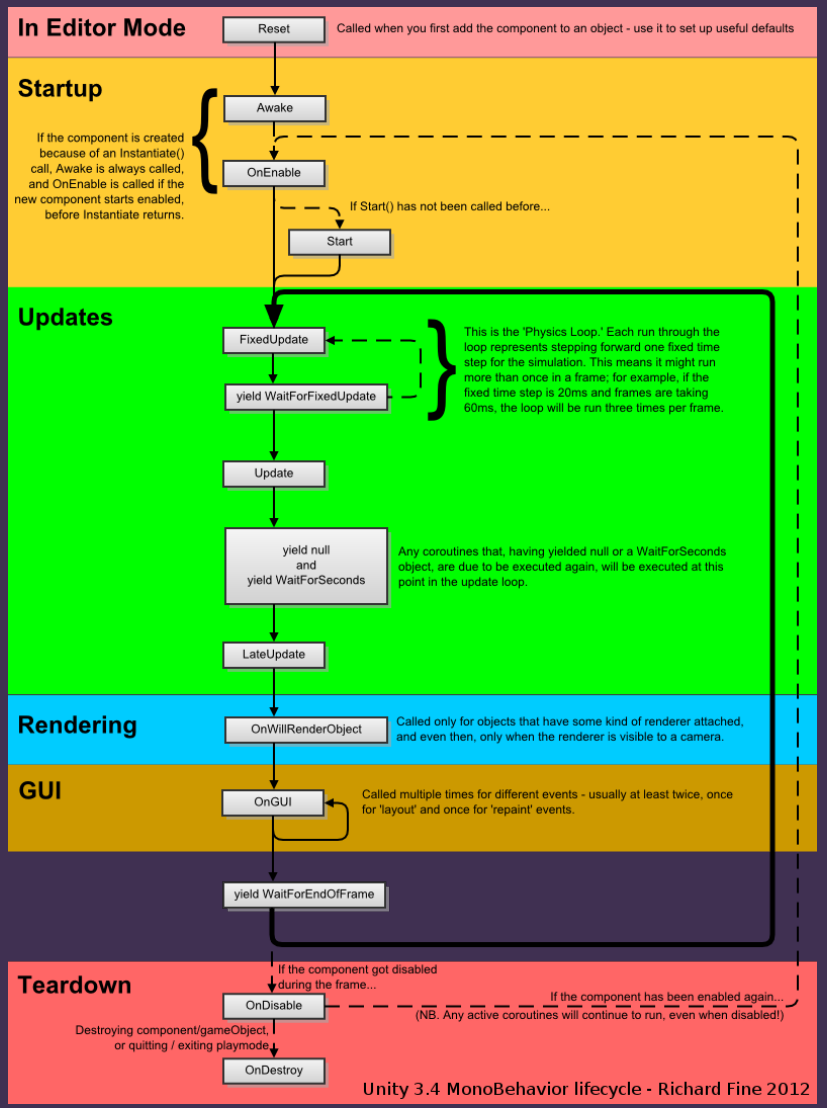


- Rendering at "irregular" intervals (with respect to update) can result in jerky movement
- Solution: **interpolate** between the two previous updates
  - E.g. if the render falls exactly halfway between two updates, render each object exactly halfway between its positions **before** and **after** the most recent update

Further information on fixed time steps

- http://gafferongames.com/game-physics/fix-your-timestep/
- http://gameprogrammingpatterns.com/game-loop.html

The "main loop" in Unity



Summary

- The **main loop** of a game runs once per frame, and handles **input**, **updating** and **rendering**
- Using a **fixed time step** is a good idea, but be careful of **stalling**