COMP220: Graphics & Simulation

1: The graphics pipeline

Learning outcomes

By the end of today's session, you will be able to:

- **Recall** the key stages of the graphics pipeline
- **Explain** the differences between a CPU and a GPU
- **Write** basic programs using SDL and OpenGL

Course introduction

From the module guide

This module will introduce you to the techniques of 3D graphics rendering and physics simulation used in modern computer games. Using the OpenGL library, you will develop an understanding of the 3D graphics pipeline, and how to program the GPU to produce advanced graphical effects.

Topic schedule

On LearningSpace...

Assignment 1: Portfolio task

Proposal due **this time next week** (29th September)

Assignment 2: Research journal

Work on it **in parallel** to your portfolio task!

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Work on it **in parallel** to your portfolio task!
Don't forget to update the wiki!

Graphics and simulation hardware

How computers work?

"A computer is like a small cardboard box. Inside this box lives an elf. The elf obeys instructions from my program, in the order they are given. Some instructions tell the elf to draw pictures onto the screen."

https://blogs.msdn.microsoft.com/shawnhar/2008/03/31/an-elf-in-a-box/

How computers really work

"A computer is like a cardboard box inhabited by a pair of elves, Charles Pitchwife Underhill plus his younger sibling George Pekkala Underhill (both more commonly known by their initials)."

https://blogs.msdn.microsoft.com/shawnhar/2008/03/31/an-elf-in-a-box/

How computers really work (cont.)

> *“Charles is smart, well educated, and fluent in dozens of languages (C, C++, C#, and Python, to name a few). George, on the other hand (...) finds it difficult to communicate with anyone other than his brother Charles, prefers to plan his day well in advance, and gets flustered if asked to change activities with insufficient warning. He has an amazing ability to multiply floating point numbers, especially enjoying computations that involve vectors and matrices.”*

https://blogs.msdn.microsoft.com/shawnhar/2008/03/31/an-elf-in-a-box/

How computers really work (cont.)

“When you run a program on this computer, Charles reads it and does whatever it says. Any time he encounters a graphics drawing instruction, he notes that down on a piece of paper. At some later point (when the paper fills up, or if he sees a Present instruction) he translates the entire paper from the original language into a secret code which only he and George can understand, then hands these translated instructions to his brother, who carries them out.”

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  - Optimised for performing the same calculation on several thousand vertices or pixels at once

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PCI
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- Now PhysX is Nvidia's middleware for performing physics simulation on the GPU

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- Deep learning

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- Most general-purpose game engines (e.g. Unity, Unreal) support several graphics APIs
- On this module we will use **OpenGL** (but the principles are transferable)

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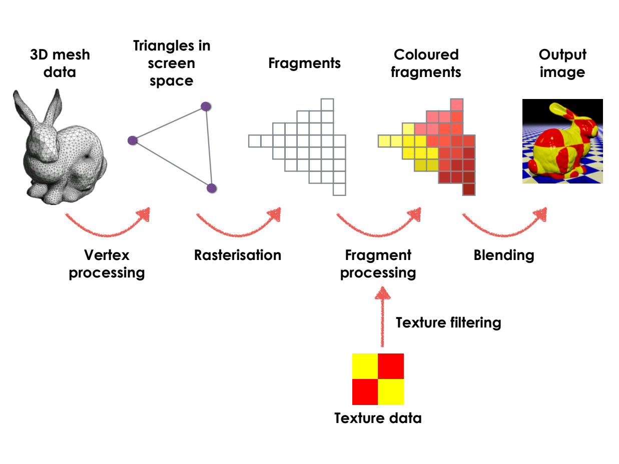
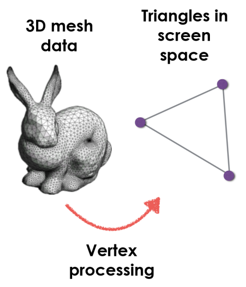
The 3D graphics pipeline

The 3D graphics pipeline



Vertex processing



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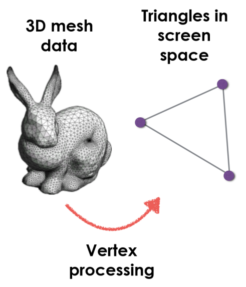


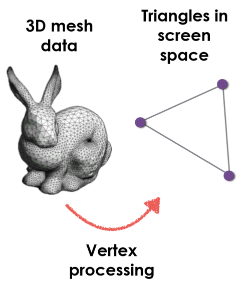
3D mesh data

Triangles in screen space

Vertex processing

- Geometry is provided to the GPU as a **mesh** of **triangles**

Vertex processing



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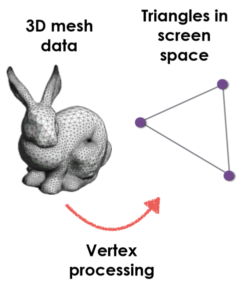

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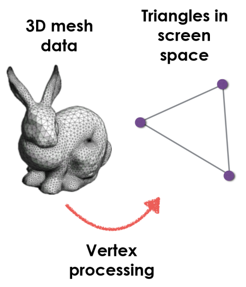

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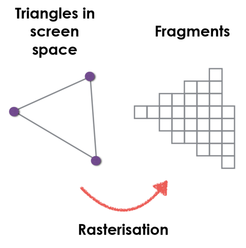
- May also apply particle simulations, skeletal animations or deformations, etc.

Rasterisation



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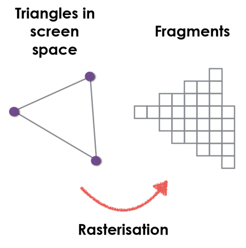

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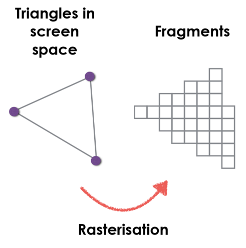

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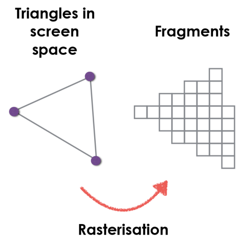

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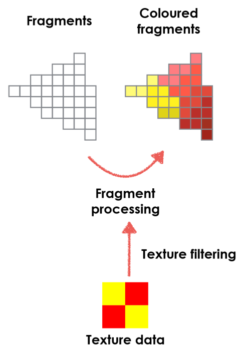
- In practical terms, “fragment” = “pixel”
- Vertex processor can associate **data** with each vertex; this is **interpolated** across the fragments

Fragment processing



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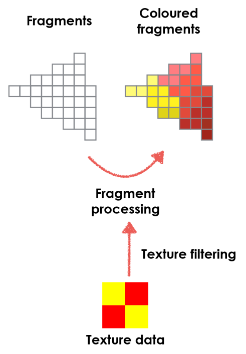

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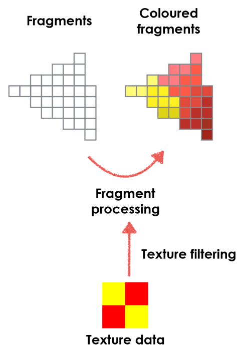

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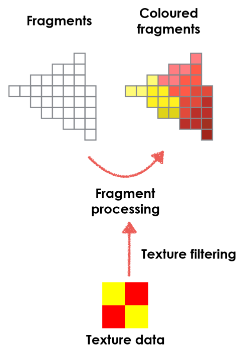
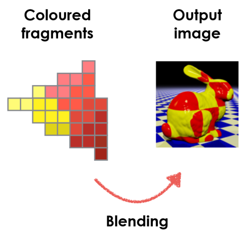


- Determine the **colour** of each fragment covered by the triangle
- **Textures** are 2D images that can be **wrapped** onto a 3D object
- Colour is calculated based on **texture**, **lighting** and other properties of the surface being rendered (e.g. shininess, roughness)

Blending



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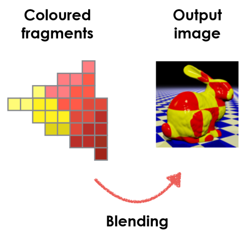

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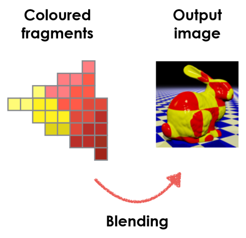

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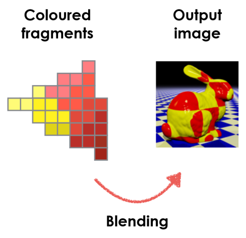

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- **Alpha blending**: combine the old and new colours for a semi-transparent appearance

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- **Vertex shader**: responsible for geometric transformations, deformations, and projection
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- Vertex shader and fragment shader are separate programs, but the vertex shader can pass arbitrary values through to the fragment shader

Your first OpenGL program

SDL and OpenGL

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- We need something else to handle windows, events, audio etc

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- We need something else to handle windows, events, audio etc
- We will use our old friend **SDL**

Live coding

`https://github.com/Falmouth-Games-Academy/bsc-live-coding`

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SDL_GL_SetAttribute(SDL_GL_CONTEXT_PROFILE_MASK,  ↩
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- ... but we do need `SDL_GLContext`

Clearing the screen

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With SDL:

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With OpenGL:

```
glClearColor(1.0f, 0.5f, 0.0f, 1.0f);
glClear(GL_COLOR_BUFFER_BIT);
SDL_GL_SwapWindow(window);
```

Our first triangle

http://www.opengl-tutorial.org/beginners-tutorials/tutorial-2-the-first-triangle/

Debrief

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