



COMP220: Graphics & Simulation

3: Vertices, Transforms & Projections



Worksheet Schedule

| Worksheet | Start | Formative deadline |
|--------------------|--------|-----------------------------------|
| 1: Framework | Week 2 | Mon 15th Feb 4pm (Week 4) |
| 2: Basic scene | Week 4 | Mon 1st Mar 4pm (Week 6) |
| 3: Plan/prototype | Week 6 | Mon 15th Mar 4pm (Week 8) |
| 4: Final iteration | Week 8 | Mon 12th Apr 4pm (Week 10) |

Learning outcomes

By the end of this week, you should be able to:

- ▶ **Recall** alternative ways to represent mesh vertices in memory.
- ▶ **Apply** basic transforms using the GLM library.
- ▶ **Explain** the constituents of the model-view-projection matrix and how it can be used to create a first-person camera controller.

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 - ▶ **Compare** different ways to store vertex data in memory.
 - ▶ **Review** the transforms required to display 3D objects on a 2D screen.
- ▶ Workshop (sync):
 - ▶ **Adapt** our basic triangle implementation to draw meshes with multiple triangles efficiently.
 - ▶ **Experiment** with creating transforms using GLM and using them to move objects and the camera.

Schedule

| | |
|-------------|--|
| 16:00-16:10 | Arrival, sign-in & overview |
| 16:10-16:30 | Demo & Exercise: Element Buffers |
| 16:30-16:40 | Introduction to GLM |
| 16:40-17:10 | Demo & Exercise: Transforms in GLM |
| 17:10-17:30 | Demo & Exercise: Model, View, Projection |
| 17:30-18:00 | Demo & Exercise: Camera Controller |

Transformations in GLM



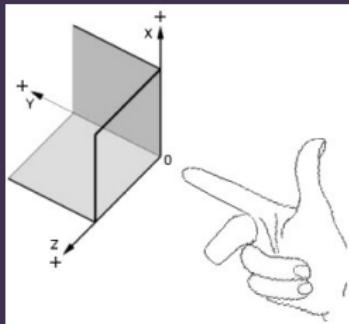
Right hand rule

Right hand rule

OpenGL uses a **right-handed coordinate system**

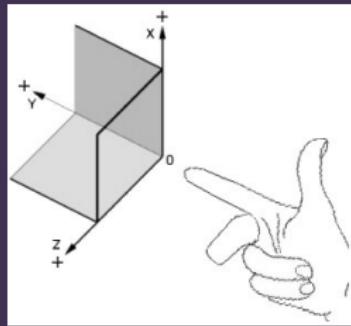
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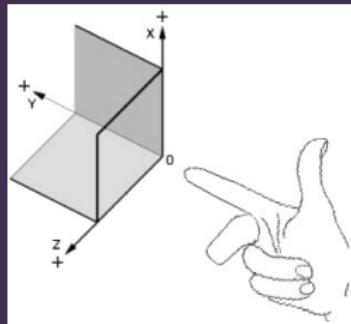
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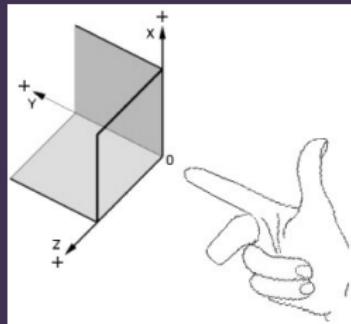
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- ▶ The **z-axis** points **out** of the screen

Transformations and matrices

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- ▶ Multiplying a vector by the matrix **applies** the transformation



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- ▶ Lets us perform calculations with vectors and matrices in C++
- ▶ GLM types can be passed into shaders as uniforms, e.g.

```
// transformLocation points to a uniform of type mat4
glm::mat4 transform = ...;
glUniformMatrix4fv(transformLocation, 1, GL_FALSE,
                    glm::value_ptr(transform));
```

Identity

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```
// Default constructor for glm::mat4
// creates an identity matrix
glm::mat4 transform;
```

Translation

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```
transform = glm::translate(transform,  
                           glm::vec3(0.3f, 0.5f, 0.0f));
```

Scaling

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```
transform = glm::scale(transform,  
                      glm::vec3(1.2f, 0.5f, 1.0f));
```

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```
float angle = glm::pi<float>() * 0.5f;  
glm::vec3 axis(0, 0, 1);  
transform = glm::rotate(transform, angle, axis);
```

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- ▶ Transformations **do not commute** in general — changing the order will change the result
- ▶ The order they are applied is the **reverse** of what you might think — i.e. the above rotates **then** translates

Creating the model, view, projection matrix in GLM



The model matrix

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Exactly what we've been doing so far today...

The view matrix

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Need to translate and rotate the scene so that the “camera” is at (0,0,0) and looking in the negative z direction

```
glm::mat4 view = glm::lookAt(  
    glm::vec3(2, 0, 2),      // eye  
    glm::vec3(0, 0, 0),      // centre  
    glm::vec3 up(0, 1, 0)    // up  
) ;
```

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- ▶ `eye` is the position of the camera
- ▶ `centre` is a point for the camera to look at
- ▶ `up` is which direction is “up” for the camera (usually the positive y-axis)

The projection matrix

The projection matrix

```
glm::mat4 projection = glm::perspective(  
    glm::radians(45.0f), // field of view  
    4.0f / 3.0f,         // aspect ratio  
    0.1f,                // near clip plane  
    100.0f               // far clip plane  
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Also available: `glm::ortho` for orthographic projection

First person camera control



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- ▶ Represent the player's **orientation** by Euler angles
- ▶ Mouse events change these angles
- ▶ View matrix is calculated using position and orientation
- ▶ To move forwards, use the Euler angles to find the "forward" vector, and offset the position by this vector

Keyboard and mouse in SDL

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Use `SDL_GetKeyboardState` instead of handling individual keyboard events

- ▶ Allows us to check on every frame whether the key is held down
- ▶ Otherwise, the player will move jerkily according to the key repeat rate