COMP220: Graphics & Simulation

4: Meshes and movement

Agenda

- Portfolio task check-in (sprint planning)
- Complex meshes (goodbye triangle, hello cube!)
- First-person camera control

Next week

Next week

- Timetable change: COMP220 lecture is on **Wednesday morning** in Seminar D

Next week

- Timetable change: COMP220 lecture is on **Wednesday morning** in Seminar D
- **Compulsory** catch-up tutorials on Tuesday 18th, in the afternoon

Next week

- Timetable change: COMP220 lecture is on **Wednesday morning** in Seminar D
- **Compulsory** catch-up tutorials on Tuesday 18th, in the afternoon
  - Book now – if you haven't booked by Friday 5pm then I will book for you!

Next week

- Timetable change: COMP220 lecture is on **Wednesday morning** in Seminar D
- **Compulsory** catch-up tutorials on Tuesday 18th, in the afternoon
  - Book now – if you haven't booked by Friday 5pm then I will book for you!
  - If you can't make it on Tuesday afternoon, let me know ASAP so that we can arrange another time

Portfolio task check-in

Portfolio task check-in

- Please show me your **Trello board** now

Portfolio task check-in

- Please show me your **Trello board** now
- You are now in your **first sprint**

Portfolio task check-in

- Please show me your **Trello board** now
- You are now in your **first sprint**
- Your first sprint review is **in 2 weeks**

FALMOUTH
UNIVERSITY

More complex meshes

Winding order

Winding order

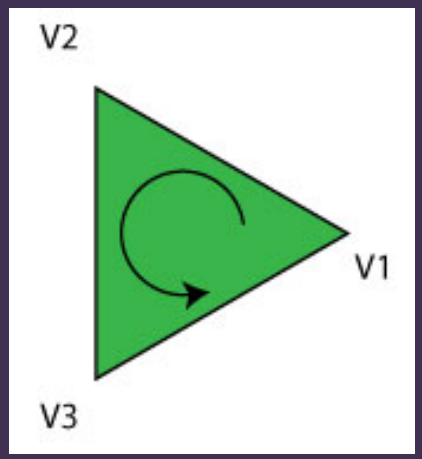
- It is sometimes important to know which side of a triangle is the "front" and which is the "back"

Winding order

- It is sometimes important to know which side of a triangle is the "front" and which is the "back"
- OpenGL determines this by **winding order**

Winding order

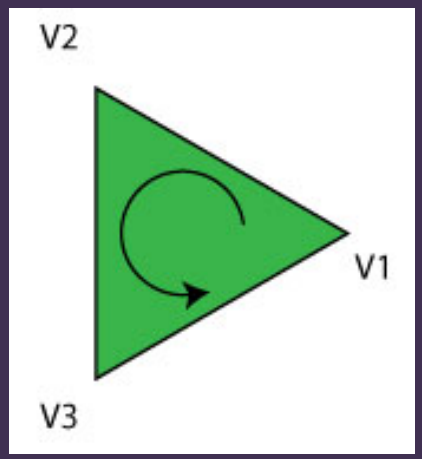
- It is sometimes important to know which side of a triangle is the "front" and which is the "back"
- OpenGL determines this by **winding order**



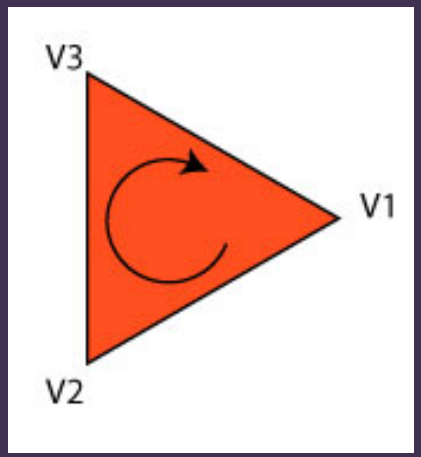
If the vertices go **anticlockwise**, you are looking at the **front**

Winding order

- It is sometimes important to know which side of a triangle is the "front" and which is the "back"
- OpenGL determines this by **winding order**



If the vertices go **anticlockwise**, you are looking at the **front**



If the vertices go **clockwise**, you are looking at the **back**

Backface culling

Backface culling

```
glEnable(GL_CULL_FACE);
```

Backface culling

```
glEnable(GL_CULL_FACE);
```

- This will cause only the front faces of triangles to be drawn

Backface culling

```
glEnable(GL_CULL_FACE);
```

- This will cause only the front faces of triangles to be drawn
- Triangles whose front face is not visible will be **culled**

Backface culling

```
glEnable(GL_CULL_FACE);
```

- This will cause only the front faces of triangles to be drawn
- Triangles whose front face is not visible will be **culled**
- Culled faces are not passed through the rasteriser or fragment shader

Backface culling

```
glEnable(GL_CULL_FACE);
```

- This will cause only the front faces of triangles to be drawn
- Triangles whose front face is not visible will be **culled**
- Culled faces are not passed through the rasteriser or fragment shader
- Saves time, and should make no difference to appearance — as long as all meshes are closed and have correct winding

When backface culling goes bad?

Passing coordinates

Passing coordinates

- Like many C functions, `glBufferData` takes an array as a **pointer** and a **size**

Passing coordinates

- Like many C functions, `glBufferData` takes an array as a **pointer** and a **size**

```
GLfloat vertexPositions[] = {
    -0.5f, -0.5f, 0.0f,
    0.5f, -0.5f, 0.0f,
    0.0f,  0.5f, 0.0f,
};

glBufferData(GL_ARRAY_BUFFER,
    sizeof(vertexPositions), // the size
    vertexPositions,         // the pointer
    GL_STATIC_DRAW);
```

Passing vertices

Passing vertices

- `glm::vec3` has the same layout in memory as three `GLfloat`s, so we could also do this:

Passing vertices

- `glm::vec3` has the same layout in memory as three `GLfloat`s, so we could also do this:

```
glm::vec3 vertexPositions[] = {
    glm::vec3(-0.5f, -0.5f, 0.0f),
    glm::vec3(0.5f, -0.5f, 0.0f),
    glm::vec3(0.0f,  0.5f, 0.0f),
};

glBufferData(GL_ARRAY_BUFFER,
    sizeof(vertexPositions), // the size
    vertexPositions,         // the pointer
    GL_STATIC_DRAW);
```

Passing vertices

- `glm::vec3` has the same layout in memory as three `GLfloat`s, so we could also do this:

```
glm::vec3 vertexPositions[] = {
    glm::vec3(-0.5f, -0.5f, 0.0f),
    glm::vec3(0.5f, -0.5f, 0.0f),
    glm::vec3(0.0f,  0.5f, 0.0f),
};

glBufferData(GL_ARRAY_BUFFER,
    sizeof(vertexPositions), // the size
    vertexPositions,         // the pointer
    GL_STATIC_DRAW);
```

- The third argument to `glBufferData` is a `void*`, which can accept any pointer type

Vectors of vectors

Vectors of vectors

- We can use a `std::vector` instead of a C-style array:

Vectors of vectors

- We can use a `std::vector` instead of a C-style array:

```
std::vector<glm::vec3> vertexPositions;
vertexPositions.push_back(...);

glBufferData(GL_ARRAY_BUFFER,
    vertexPositions.size() * sizeof(glm::vec3),
    vertexPositions.data(),
    GL_STATIC_DRAW);
```

Vectors of vectors

- We can use a `std::vector` instead of a C-style array:

```
std::vector<glm::vec3> vertexPositions;
vertexPositions.push_back(...);

glBufferData(GL_ARRAY_BUFFER,
    vertexPositions.size() * sizeof(glm::vec3),
    vertexPositions.data(),
    GL_STATIC_DRAW);
```

- `data()` returns a pointer to the data inside a `std::vector`

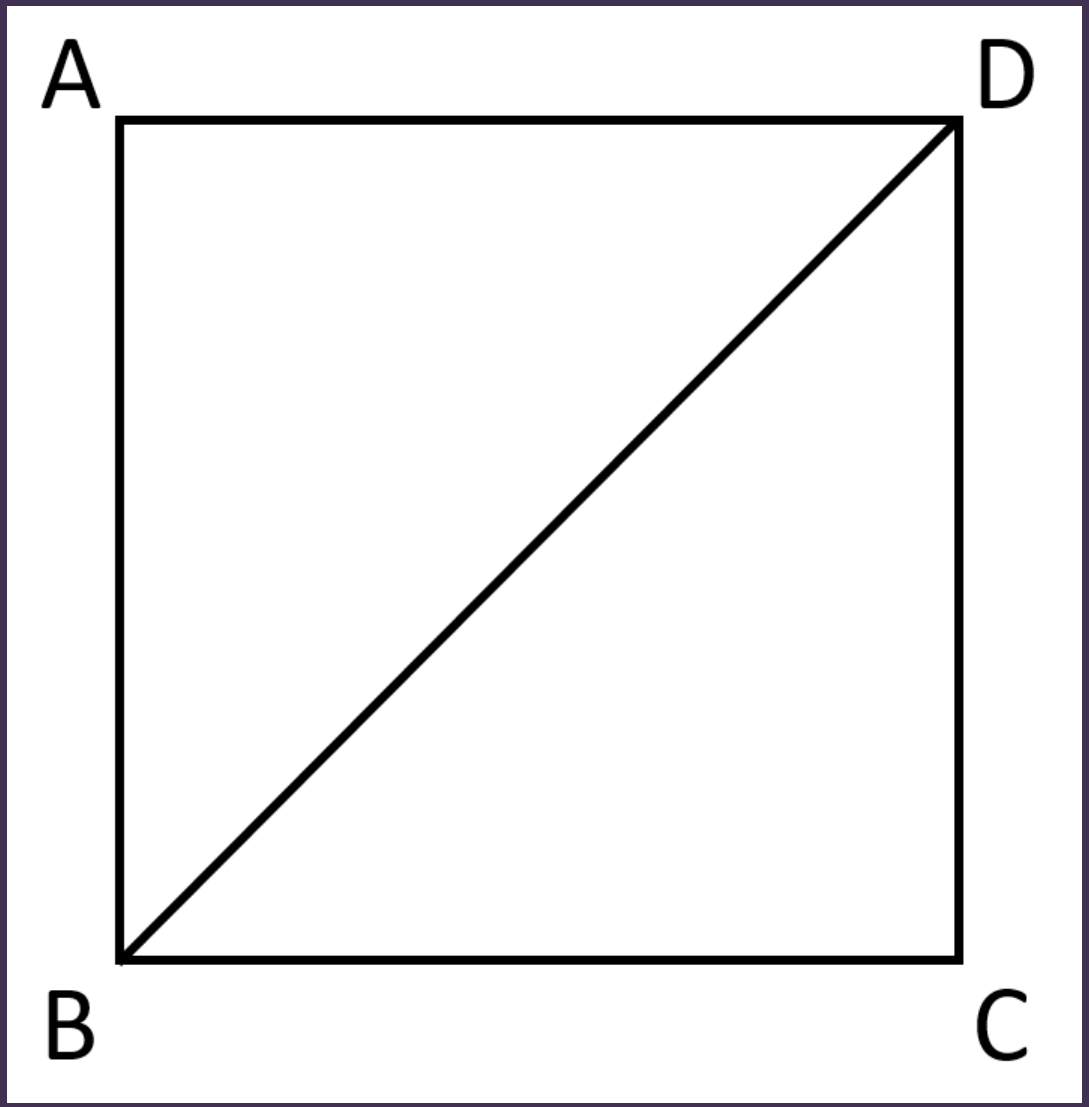
Vectors of vectors

- We can use a `std::vector` instead of a C-style array:

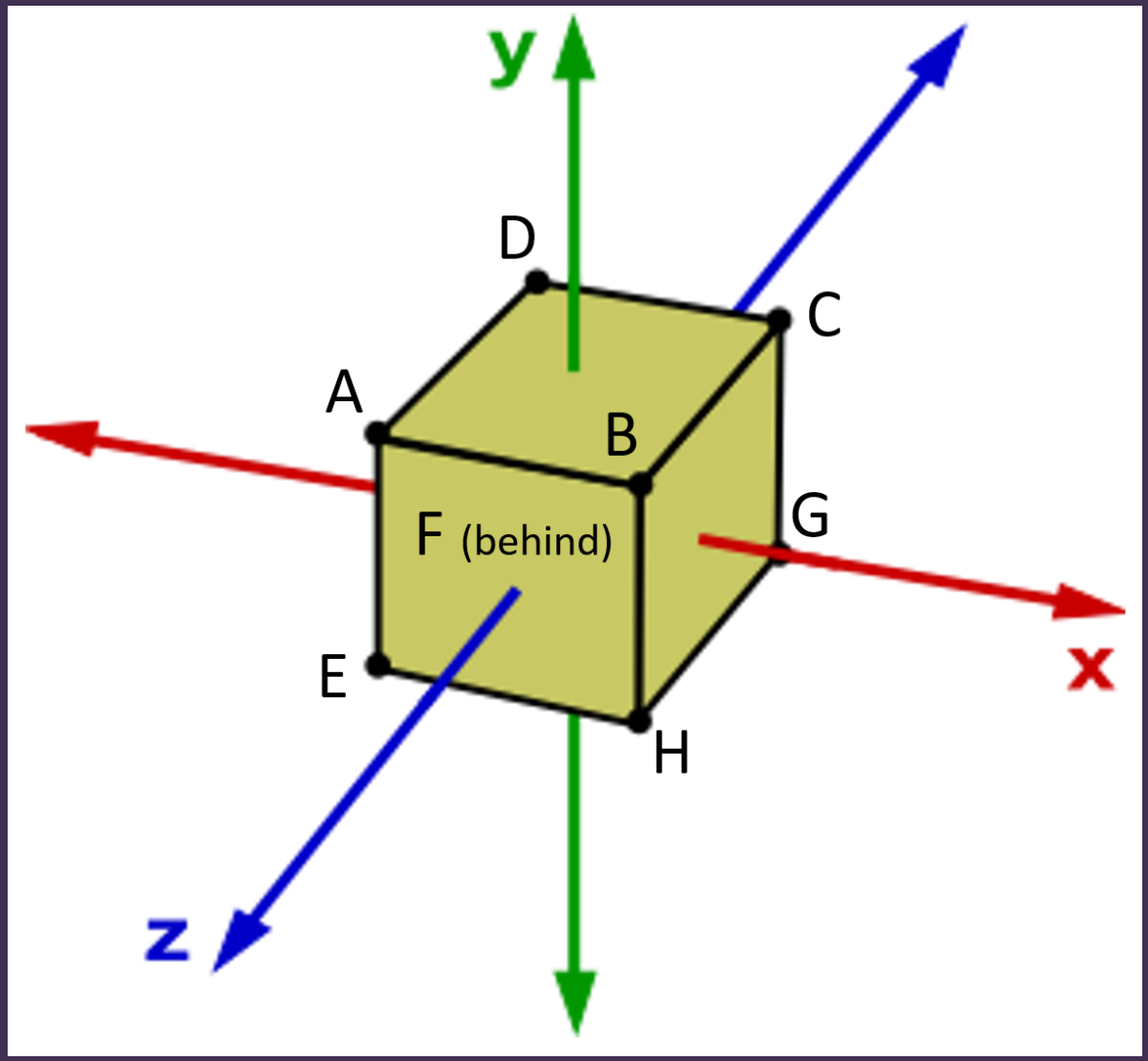
```
std::vector<glm::vec3> vertexPositions;
vertexPositions.push_back(...);

glBufferData(GL_ARRAY_BUFFER,
    vertexPositions.size() * sizeof(glm::vec3),
    vertexPositions.data(),
    GL_STATIC_DRAW);
```

- `data()` returns a pointer to the data inside a `std::vector`
- `size()` returns the number of elements, so multiplying by `sizeof(glm::vec3)` gives the size in bytes

Let's draw a square!



Let's draw a cube!



FALMOUTH
UNIVERSITY

First person camera control

The plan

The plan

- Represent the player's **position** by a 3D vector

The plan

- Represent the player's **position** by a 3D vector
- Represent the player's **orientation** by Euler angles

The plan

- Represent the player's **position** by a 3D vector
- Represent the player's **orientation** by Euler angles
- Mouse events change these angles

The plan

- Represent the player's **position** by a 3D vector
- Represent the player's **orientation** by Euler angles
- Mouse events change these angles
- View matrix is calculated using position and orientation

The plan

- Represent the player's **position** by a 3D vector
- 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

Keyboard and mouse in SDL

Use **relative mouse mode**

Keyboard and mouse in SDL

Use **relative mouse mode**

- Hides the mouse pointer

Keyboard and mouse in SDL

Use **relative mouse mode**

- Hides the mouse pointer
- Prevents the mouse pointer from hitting the edge of the screen

Keyboard and mouse in SDL

Use **relative mouse mode**

- Hides the mouse pointer
- Prevents the mouse pointer from hitting the edge of the screen
- Gives us the distance the mouse has moved since last frame, rather than its current position

Keyboard and mouse in SDL

Use **relative mouse mode**

- Hides the mouse pointer
- Prevents the mouse pointer from hitting the edge of the screen
- Gives us the distance the mouse has moved since last frame, rather than its current position

Use `SDL_GetKeyboardState` instead of handling individual keyboard events

Keyboard and mouse in SDL

Use **relative mouse mode**

- Hides the mouse pointer
- Prevents the mouse pointer from hitting the edge of the screen
- Gives us the distance the mouse has moved since last frame, rather than its current position

Use `SDL_GetKeyboardState` instead of handling individual keyboard events

- Allows us to check on every frame whether the key is held down

Keyboard and mouse in SDL

Use **relative mouse mode**

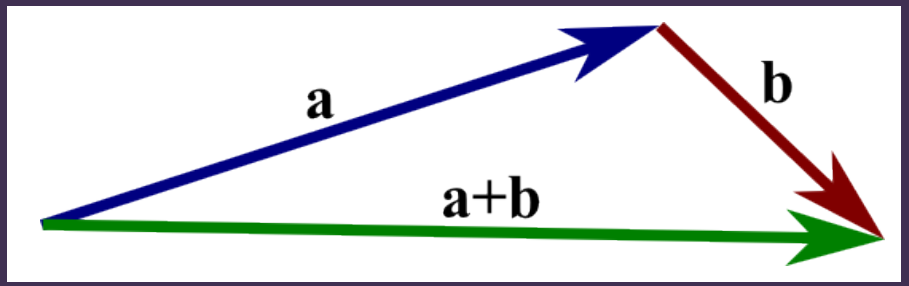
- Hides the mouse pointer
- Prevents the mouse pointer from hitting the edge of the screen
- Gives us the distance the mouse has moved since last frame, rather than its current position

Use `SDL_GetKeyboardState` instead of handling individual keyboard events

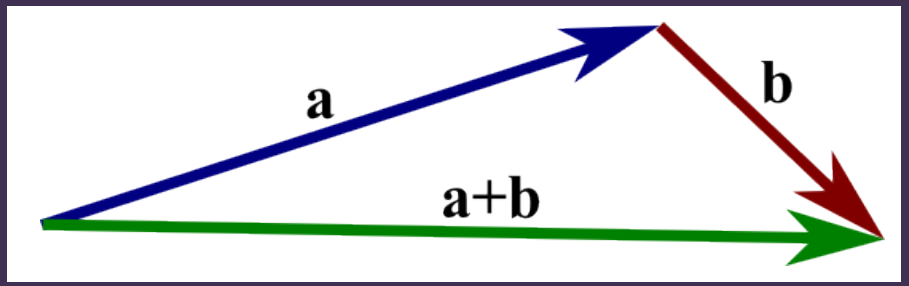
- Allows us to check on every frame whether the key is held down
- Otherwise, the player will move jerkily according to the key repeat rate

Vector addition

Vector addition

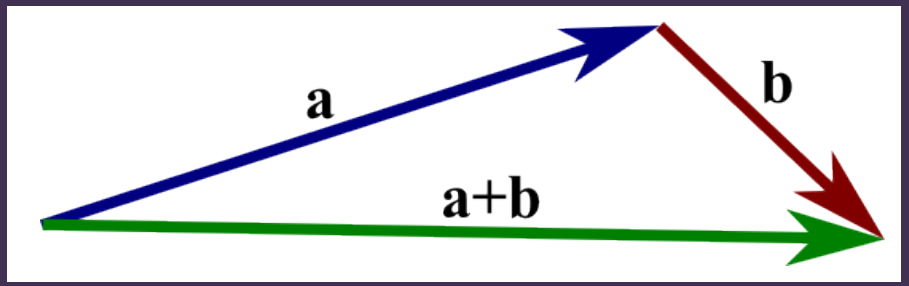


Vector addition



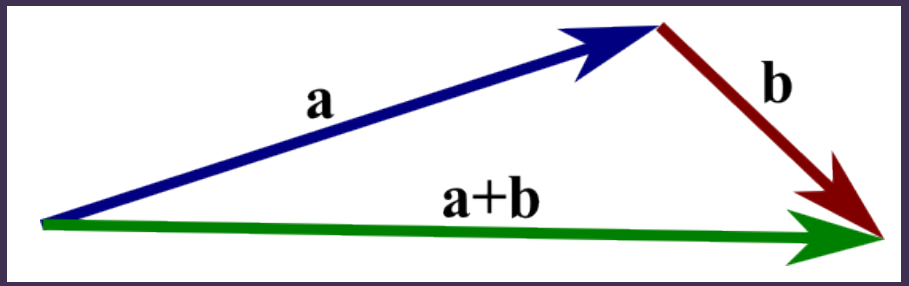
- E.g. if *a* is current position, and

Vector addition



- E.g. if *a* is current position, and
- *b* is the distance and direction we want to move, then

Vector addition



- E.g. if a is current position, and
- b is the distance and direction we want to move, then
- $a + b$ is the new position

Addition in homogeneous coordinates

Addition in homogeneous coordinates

- Recall: homogeneous coordinates have an extra w component, i.e. (x, y, z, w)

Addition in homogeneous coordinates

- Recall: homogeneous coordinates have an extra w component, i.e. (x, y, z, w)
- $w = 1$ for positions, $w = 0$ for offsets

Addition in homogeneous coordinates

- Recall: homogeneous coordinates have an extra w component, i.e. (x, y, z, w)
- $w = 1$ for positions, $w = 0$ for offsets

offset + offset = offset $\quad w = 0 + 0 = 0$

Addition in homogeneous coordinates

- Recall: homogeneous coordinates have an extra w component, i.e. (x, y, z, w)
- $w = 1$ for positions, $w = 0$ for offsets

offset	+	offset	=	offset	$w = 0 + 0 = 0$
position	+	offset	=	position	$w = 1 + 0 = 1$

Addition in homogeneous coordinates

- Recall: homogeneous coordinates have an extra w component, i.e. (x, y, z, w)
- $w = 1$ for positions, $w = 0$ for offsets

offset	+	offset	=	offset	$w = 0 + 0 = 0$
position	+	offset	=	position	$w = 1 + 0 = 1$
position	+	position	=	???	$w = 1 + 1 = 2$

Unit vectors

Unit vectors

- A **unit vector** is a vector of length 1

Unit vectors

- A **unit vector** is a vector of length 1
- I.e. $\sqrt{x^2 + y^2 + z^2} = 1$ (Pythagoras)

Unit vectors

- A **unit vector** is a vector of length 1
- I.e. $\sqrt{x^2 + y^2 + z^2} = 1$ (Pythagoras)
- Useful to represent **direction**

Unit vectors

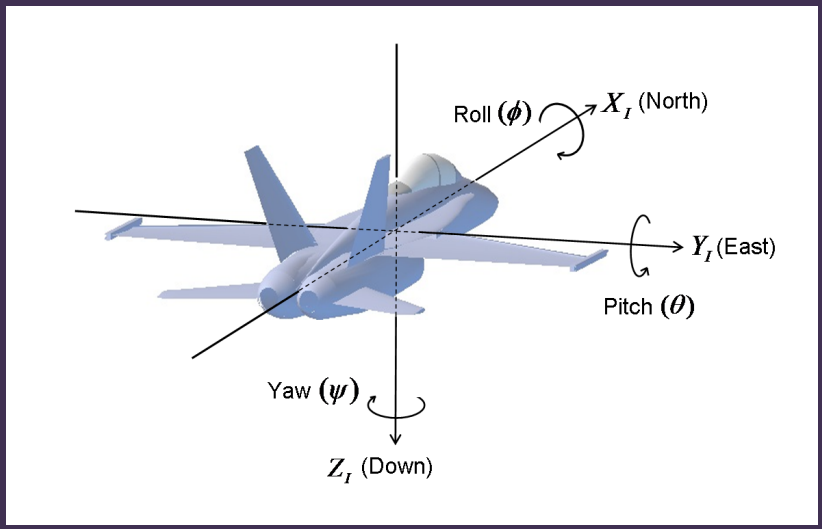
- A **unit vector** is a vector of length 1
- I.e. $\sqrt{x^2 + y^2 + z^2} = 1$ (Pythagoras)
- Useful to represent **direction**
- Multiplying a vector of length a by a number b gives a vector of length $a \times b$, parallel to the original vector

Unit vectors

- A **unit vector** is a vector of length 1
- I.e. $\sqrt{x^2 + y^2 + z^2} = 1$ (Pythagoras)
- Useful to represent **direction**
- Multiplying a vector of length a by a number b gives a vector of length $a \times b$, parallel to the original vector
- So multiplying a unit vector by b gives a vector of length b, parallel to the unit vector

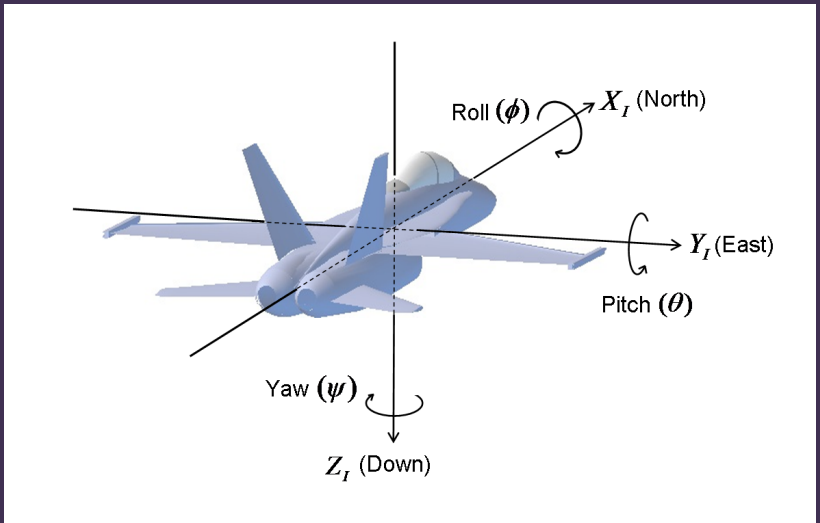
Representing look direction

Representing look direction

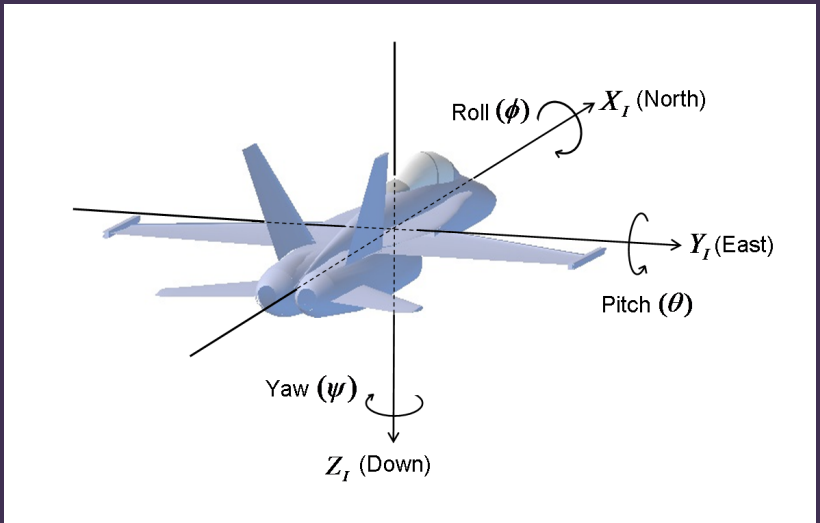


Representing look direction

- Euler angles

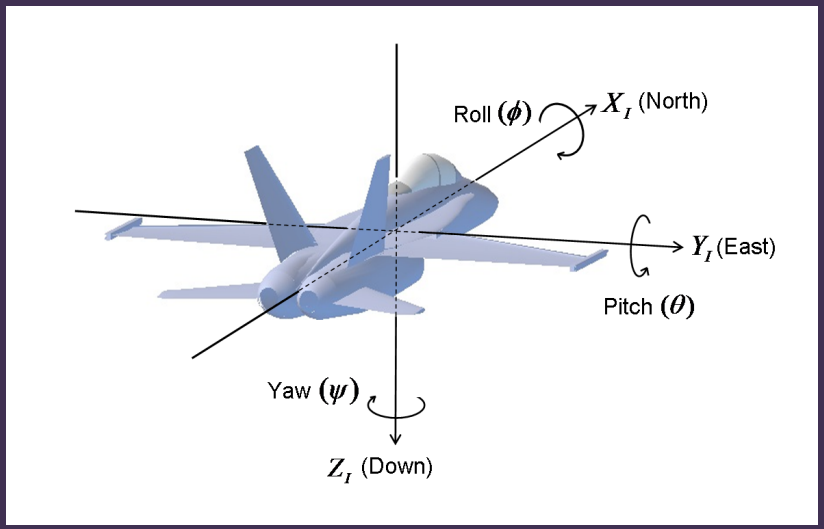


Representing look direction



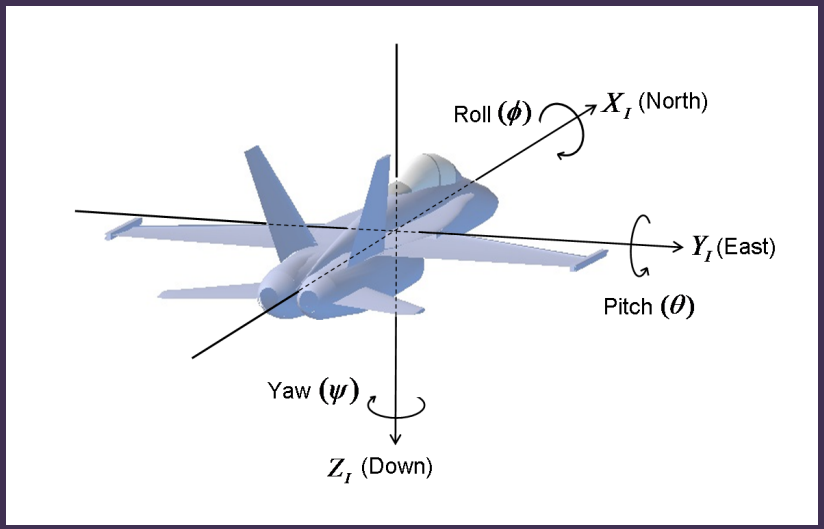
- Euler angles
- Don't need roll, just pitch and yaw

Representing look direction



- Euler angles
- Don't need roll, just pitch and yaw
- (Not using roll eliminates the gimbal lock problem)

Representing look direction



- Euler angles
- Don't need roll, just pitch and yaw
- (Not using roll eliminates the gimbal lock problem)
- Forward vector and look vector can be obtained by appropriate rotation of a unit vector