Tutorial 2

CS3241 Computer Graphics (AY23/24)

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Attendance taking

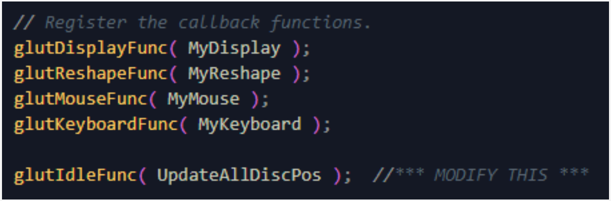
Question 1

What is a GLUT **display callback** function? Give example **events** for which the display callback function should be called.

GLUT function

GLUT: OpenGL Utility Toolkit (Lecture 2 slide 10),

a library that provides **I/O functionality** common to all window systems.



```
// Register the callback functions.
glutDisplayFunc( MyDisplay );
glutReshapeFunc( MyReshape );
glutMouseFunc( MyMouse );
glutKeyboardFunc( MyKeyboard );

glutIdleFunc( UpdateAllDiscPos );  //*** MODIFY THIS ***
```

GLUT display callback

```
glutDisplayFunc(void (*func)(void)).
```

- Takes in a function pointer to user defined display method `func`.
- Executed on each window refresh.
- OpenGL reference

Question 2

What is the use of the GLUT function `glutPostRedisplay()`?

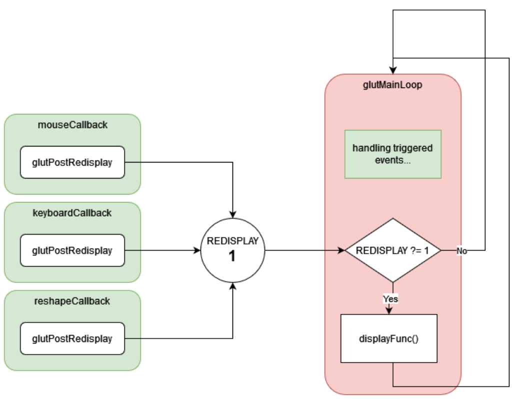
glutPostRedisplay

Redisplay: Update of the display output (usually due to a change in internal state).

The execution of the `glutPostRedisplay()` function tells GLUT to call the display callback function at the end of the current event loop.

- Sets the redisplay state.
- Multiple calls to `glutPostRedisplay` simply set the redisplay state multiple times (coalesce multiple display function calls)
- the display callback is only called once on the next cycle.

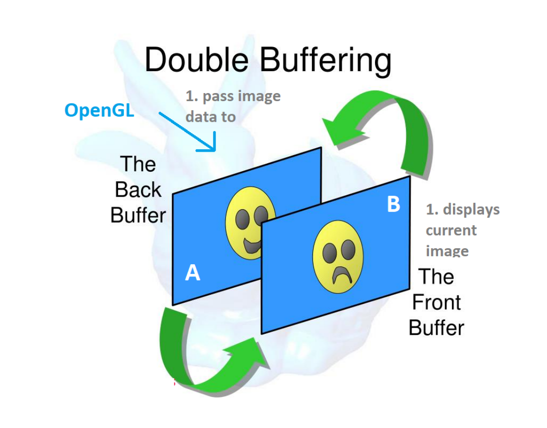
glutPostRedisplay



Question 3

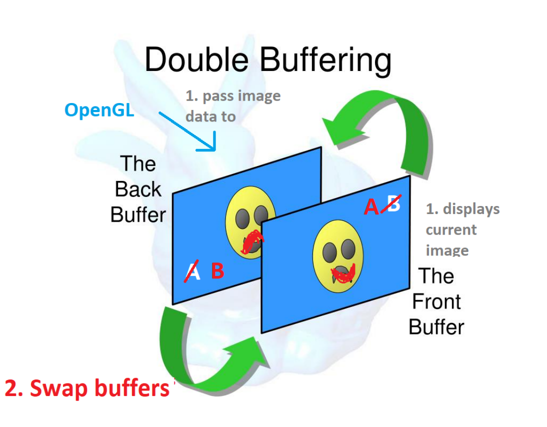
How does double buffering work?

Double buffering



- Back buffer: apply graphics **WHILE**
- Front buffer: display graphics

Double buffering

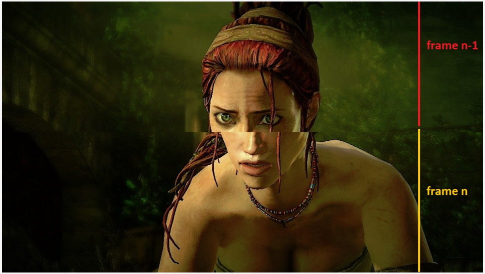


No "incomplete" frames will be visible, as the swap is only performed after the the back buffer is filled.

Question 3

Why do we use double buffering?

Prevents screen tearing



Screen tearing: when the rate of graphics feed application $\neq$ window refresh rate.

Double buffering in OpenGL

To enable double buffering: `glutInitDisplayMode`.

To perform the buffer swap in display function: `glutSwapBuffers`.

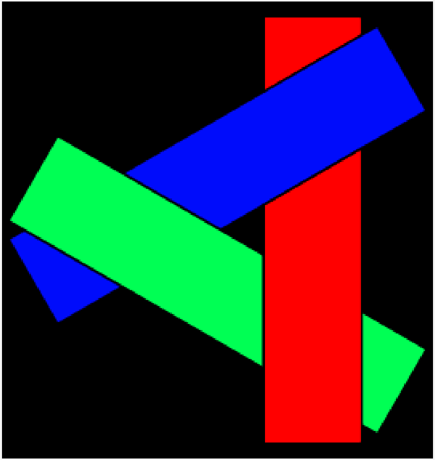
See lecture 3 slide 14.

Question 4

The use of any special hidden surface removal method is not necessary if we can sort the polygons in a back-to-front order and render these polygons in that order. (Tutorial 1 Q6)

Is it **always possible** that any set of polygons can be sorted in a back-to-front order?

Cyclic overlap



Question 5a

(A) What is an OpenGL viewport?

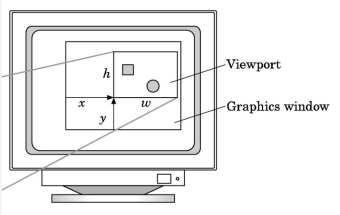
Viewport

OpenGL viewport: A rectangular region of the window in which OpenGL can draw.

Question 5b

(B) How do you specify one?

glViewport



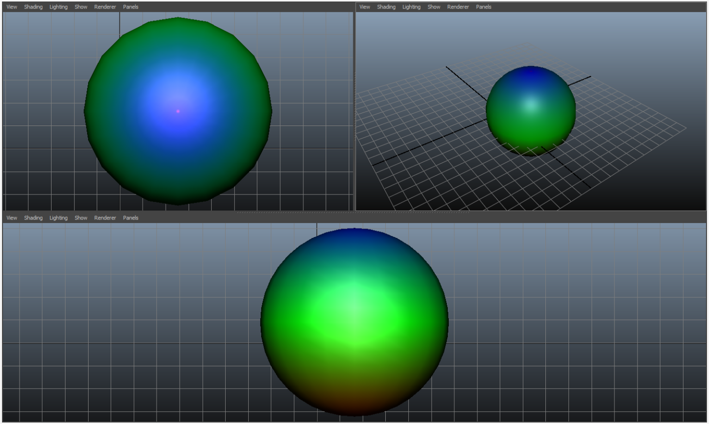
```
glViewport(GLint x, GLint y, GLsizei w, GLsizei
h)
```

Note: x, y, w, h are in window coordintes.

Question 5c

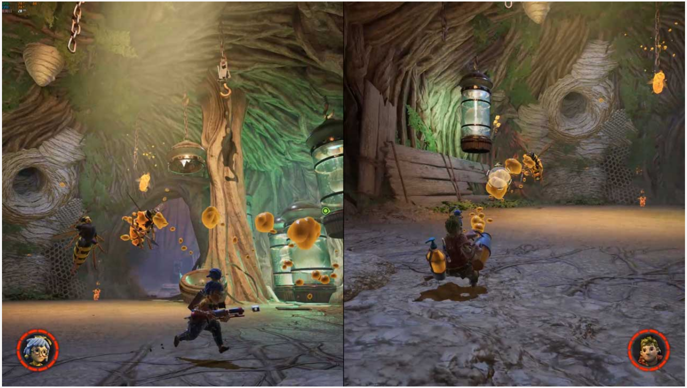
(C) Can we have **multiple viewports** in one window?

Yes!


View Shading Lighting Show Renderer Panels
View Shading Lighting Show Renderer Panels
View Shading Lighting Show Renderer Panels

[3DSMax] Each viewport has a different perspective of the same world.

Yes!



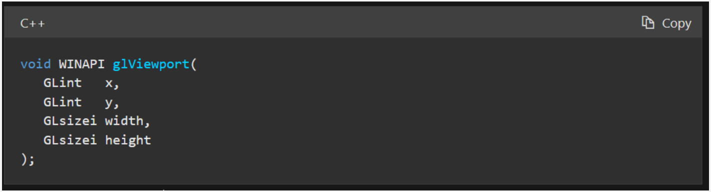
[It Takes Two] Different camera movements possible.

Question 5d, 5e

(D) Can a viewport be larger than the window?

(E) If yes, what will happen?

Yes!



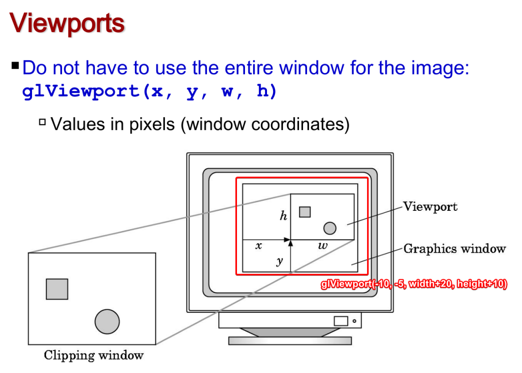
C++ Copy

```cpp
void WINAPI glViewport(
   GLint   x,
   GLint   y,
   GLsizei width,
   GLsizei height
);
```

Parameter types are `GLint` for x and y coordinates, so they can be negative and go out of the screen.

Or `width` or `height` could also exceed window size.
Viewport size is independent of window size.

Specification example



Viewports

- Do not have to use the entire window for the image: **`glViewport(x, y, w, h)`**
  - Values in pixels (window coordinates)

glViewport(-10, -5, width+20, height+10)

Consequence is that the viewport will be clipped by the window.

Question 5f

(F) When you use `glClear(GL_COLOR_BUFFER_BIT)`, are you clearing the entire window or just the viewport?

Question 5f

When you use `glClear(GL_COLOR_BUFFER_BIT)`, are you clearing the entire window or just the viewport?

Short answer: the window.
Long answer: `glClear(mask)` marks the **buffer** to be cleared. The buffer is associated with the **window** i.e. the (physically) visible area, not the (virtual) viewport.

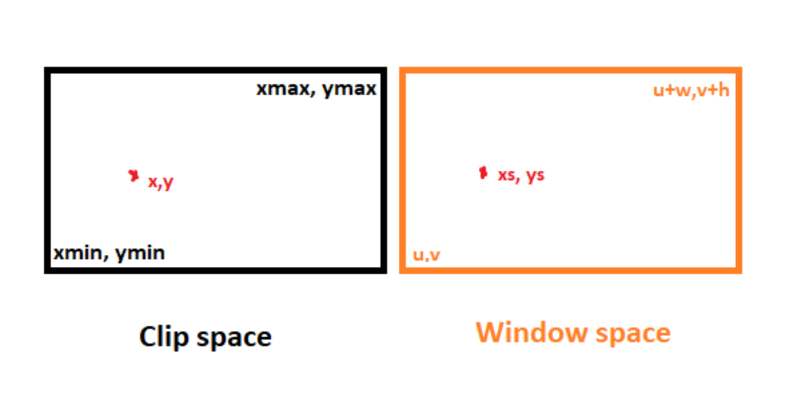
Question 6

Assume we have the following OpenGL function calls:

```
glViewport( u, v, w, h );
...
gluOrtho2D( x_min, x_max, y_min, y_max );
```

Find the mathematical expressions that map a point (x, y) that lies within the clipping rectangle to a point (xs, ys) that lies within the viewport.

Clip space to window space



$$x_s = u + (x - x_{\min})\left(\frac{w}{x_{\max} - x_{\min}}\right)$$
$$y_s = v + (y - y_{\min})\left(\frac{h}{y_{\max} - y_{\min}}\right)$$

Question 7a

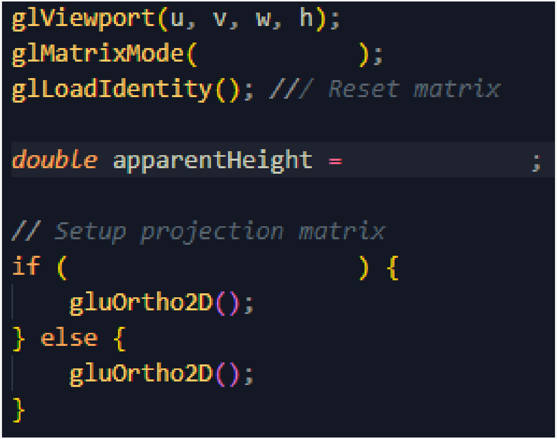
In many old CRT monitors, the pixels are not square. Let's assume the pixel width-to-height aspect ratio is 4:3.

Suppose in the **camera coordinate frame**, there is a disc in the z = 0 plane, centered at (100, 200, 0), and has a radius of 10.
You want to draw the entire disc as big as possible inside the window, and it should appear circular and not oval.

If the window size is ____, how would you set up the viewport and the orthographic projection using OpenGL?

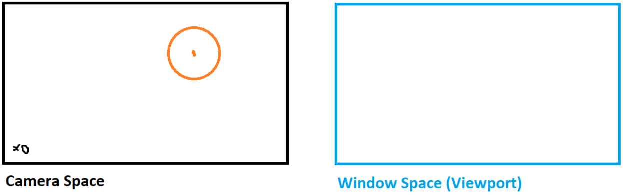
- 600×300
- 300×600
- 300×320

Template

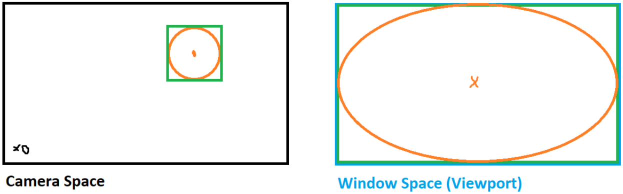


```
glViewport(u, v, w, h);
glMatrixMode(           );
glLoadIdentity(); /// Reset matrix

double apparentHeight =            ;

// Setup projection matrix
if (                     ) {
    gluOrtho2D();
} else {
    gluOrtho2D();
}
```

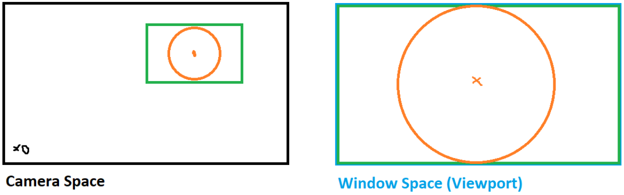
Visualize



Consider the case where the pixels are square first. Let w, h be the width and height of the viewport, c be the 2D coordinates of the center of the circle, and r be the radius.

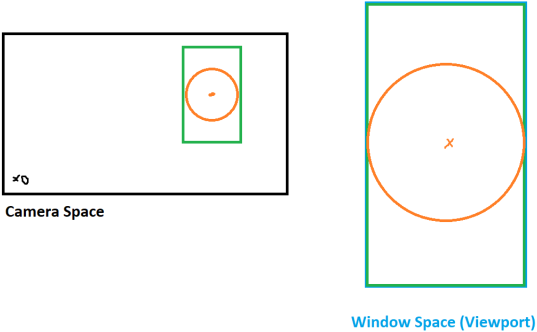


```
glViewport(0, 0, w, h);
glOrtho(c.x - r, c.x + r, c.y - r, c.y + r);
```



Assuming the pixels are square, to get this we can:

```
glViewport(0, 0, w, h);
glOrtho(c.x - r * w/h , c.x + r * w/h,
c.y - r, c.y + r);
```

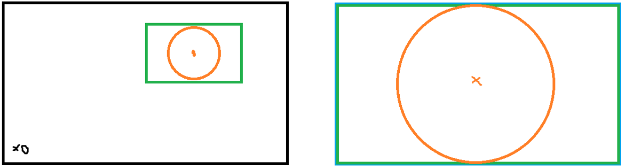


Assuming the pixels are square, to get this we can:

```
glViewport(0, 0, w, h);
glOrtho(c.x - r , c.x + r,
c.y - r * h/w, c.y + r * h/w);
```

What if we consider the 4:3 pixels?

Then we have to make sure the clipping space scales to the **apparent aspect ratio**, i.e. $\texttt{apparentWidth} = w \times \frac{4}{3}$.

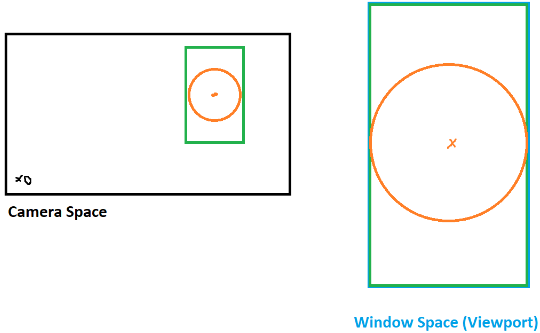


Camera Space

Window Space (Viewport)

Assuming the pixels are 4:3, to get this we can:

```
glViewport(0, 0, w, h);
glOrtho(c.x - r * apparentWidth/h ,
c.x + r * apparentWidth/h, c.y - r, c.y + r);
```



Assuming the pixels are 4:3, to get this we can:

```
glViewport(0, 0, w, h);
glOrtho(c.x - r , c.x + r,
c.y - r * h/apparentWidth,
c.y + r * h/apparentWidth);
```

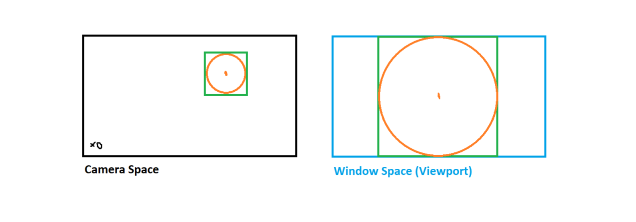
Key takeaway

In 2D orthographic projecton, aspect ratios must match between the clipping space and the window space (**assuming uniform pixels**) to not be distorted.

If the window size is ____, how would you set up the viewport and the orthographic projection using OpenGL?

- $600 \times 300 \longrightarrow \mathbf{800} \times 300$ **(horizontal)**
- $300 \times 600 \longrightarrow \mathbf{400} \times 600$ **(vertical)**
- $300 \times 320 \longrightarrow \mathbf{400} \times 320$ **(horizontal)**

Alternative: scaled viewport



The pixels are 4:3.

```
int squishedWidth = w * 3/4;
glViewport(0, w / 2 - squishedWidth / 2,
squishedWidth, h);
glOrtho(c.x - r , c.x + r, c.y - r, c.y + r);
```

You can similarly account for the case where $h > w$.

Thanks! Get the slides here after the tutorial.

https://trxe.github.io/cs3241-notes