Computer Graphics

6 - Lab - Vertex Processing 2

Yoonsang Lee
Hanyang University

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Outline

- Orthographic Projection
  - glm.ortho()

- Perspective Projection
  - glm.frustum()
  - glm.perspective()

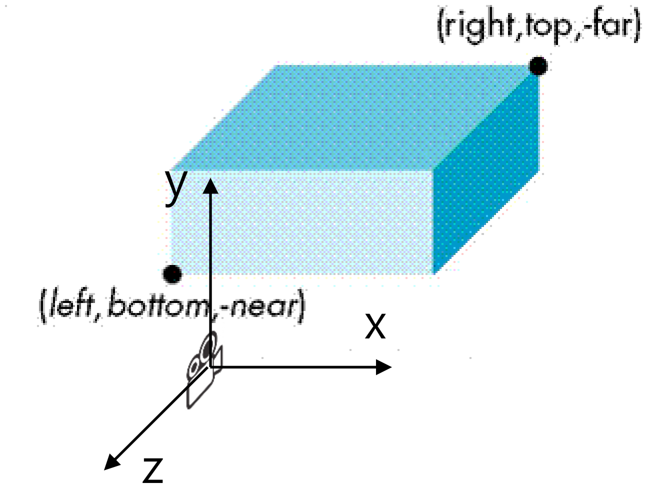
- Viewport Transformation
  - glViewPort()

Orthographic Projection - glm.ortho()

glm.ortho()

glm.ortho(**left**: *float*, **right**: *float*, **bottom**: *float*, **top**: *float*, **zNear**: *float*, **zFar**: *float*) -> ***fmat4x4***

- : Creates an orthographic projection matrix.
- Sign of zNear, zFar:
  - positive value: the plane is in front of the camera.
  - negative value: the plane is behind the camera.



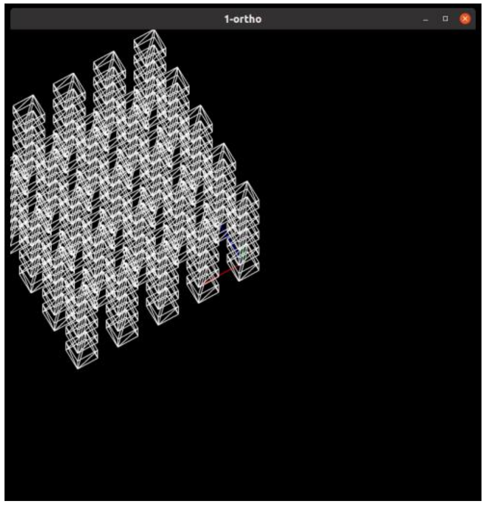
[Code] 1-ortho

- Vertex & Fragment shader: same as those in the previous example "3-lookat.py"

- Draws a cube or an array of cubes instead of a single triangle, in wireframe mode.

- Two VAOs:
  - cube VAO
  - frame VAO

- Three drawing functions:
  - draw_frame() - uses the frame VAO
  - draw_cube(), draw_cube_array() - uses the cube VAO



[Code] 1-ortho

```python
def prepare_vao_cube():
    # prepare vertex data (in main memory)
    # 36 vertices for 12 triangles
    vertices = glm.array(glm.float32,
        # position                 color
        -0.5 ,  0.5 ,  0.5 ,  1, 1, 1, # v0
         0.5 , -0.5 ,  0.5 ,  1, 1, 1, # v2
         0.5 ,  0.5 ,  0.5 ,  1, 1, 1, # v1

        -0.5 ,  0.5 ,  0.5 ,  1, 1, 1, # v0
        -0.5 , -0.5 ,  0.5 ,  1, 1, 1, # v3
         0.5 , -0.5 ,  0.5 ,  1, 1, 1, # v2
        ...
        -0.5 ,  0.5 ,  0.5 ,  1, 1, 1, # v0
        -0.5 ,  0.5 , -0.5 ,  1, 1, 1, # v4
        -0.5 , -0.5 , -0.5 ,  1, 1, 1, # v7
    )
    # the same vertex configuration as the previous "3-lookat.py" example
    ...

def prepare_vao_frame():
    # the same function as the previous "3-lookat.py" example
    ...
```

[Code] 1-ortho

```
def draw_frame(vao, MVP, MVP_loc):
    glBindVertexArray(vao)
    glUniformMatrix4fv(MVP_loc, 1, GL_FALSE, glm.value_ptr(MVP))
    glDrawArrays(GL_LINES, 0, 6)

def draw_cube(vao, MVP, MVP_loc):
    glBindVertexArray(vao)
    glUniformMatrix4fv(MVP_loc, 1, GL_FALSE, glm.value_ptr(MVP))
    glDrawArrays(GL_TRIANGLES, 0, 36)

def draw_cube_array(vao, MVP, MVP_loc):
    glBindVertexArray(vao)
    for i in range(5):
        for j in range(5):
            for k in range(5):
                MVP_cube = MVP * 
glm.translate(glm.vec3(1*i, 1*j, 1*k)) * 
glm.scale(glm.vec3(.5,.5,.5))
                glUniformMatrix4fv(MVP_loc, 1, GL_FALSE, 
glm.value_ptr(MVP_cube))
                glDrawArrays(GL_TRIANGLES, 0, 36)
```

[Code] 1-ortho

```
def main():
    ...
    while not glfwWindowShouldClose(window):
        ...
        # render in "wireframe mode"
        glPolygonMode(GL_FRONT_AND_BACK, GL_LINE)
        ...
        # orthogonal projection - try changing arguments
        P = glm.ortho(-5,5, -5,5, -10,10)

        # view matrix
        V = glm.lookAt(glm.vec3(1*np.sin(g_cam_ang), g_cam_height,
1*np.cos(g_cam_ang)), glm.vec3(0,0,0), glm.vec3(0,1,0))

        # draw world frame
        draw_frame(vao_frame, P*V*glm.mat4(), MVP_loc)
        ...
        M = glm.mat4()
        # M = R

        # draw cube w.r.t. the current frame MVP
        draw_cube(vao_cube, P*V*M, MVP_loc)

        # # draw cube array w.r.t. the current frame MVP
        # draw_cube_array(vao_cube, P*V*M, MVP_loc)
        ...
```

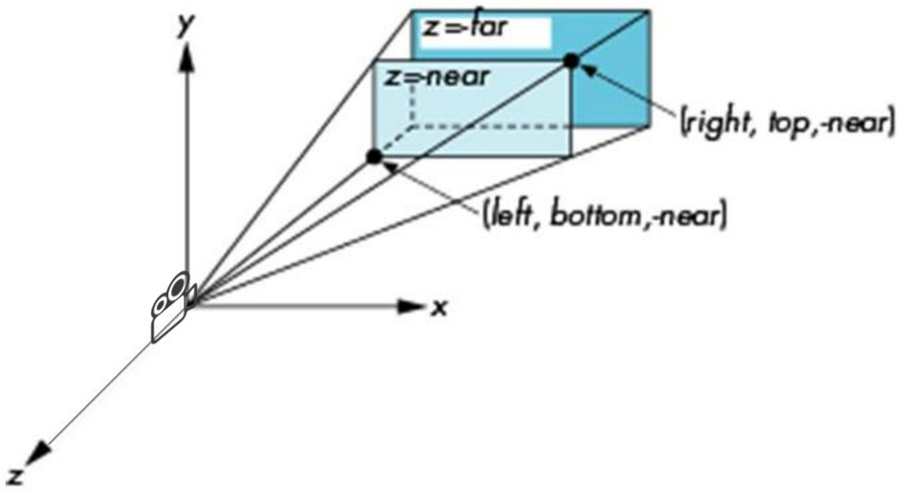
Perspective Projection
- glm.frustum()
- glm.perspective()

glm.frustum()

glm.frustum(**left**: float, **right**: float, **bottom**: float, **top**: float, **near**: float, **far**: float) -> **fmat4x4**

- : Creates a perspective projection matrix.
  - Actually, not easy to use to set a view frustum.

- Sign of near, far:
  - The values for both parameters must be positive.

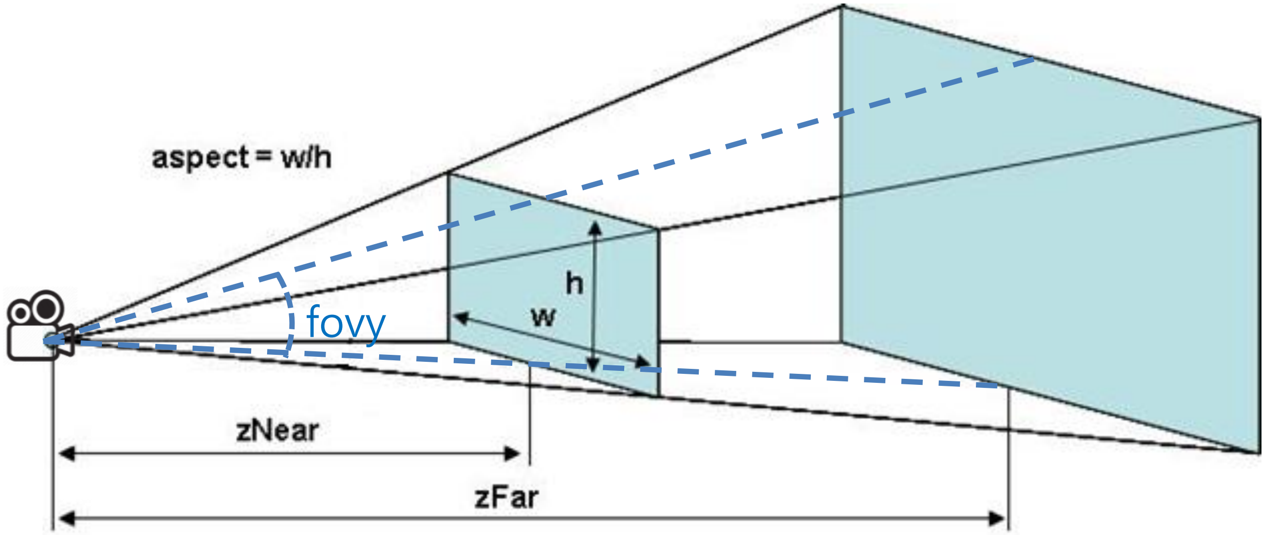


glm.perspective()

glm.perspective(**fovy**: *float*, **aspect**: *float*, **near**: *float*, **far**: *float*) -> *fmat4x4*

- **fovy**: The field of view angle, in degrees, in the y-direction.
- **aspect**: The aspect ratio that determines the field of view in the x-direction. width / height.

- : Creates a perspective projection matrix.
  - Easier to use.



[Code] 2-frustum-perspective

```
def main():
    ...
    while not glfwWindowShouldClose(window):
        ...
        # perspective projection - try changing arguments

        # perspective
        P = glm.perspective(45, 1, 1, 10)

        # # frustum
        # # P = glm.frustum(-1,1, -1,1, .1,10)
        # P = glm.frustum(-1,1, -1,1, 1,10)

        # view matrix
        V = 
glm.lookAt(glm.vec3(5*np.sin(g_cam_ang),g_cam_height,5*np.cos(g_c
am_ang)), glm.vec3(0,0,0), glm.vec3(0,1,0))

        ...
```

Quiz 3

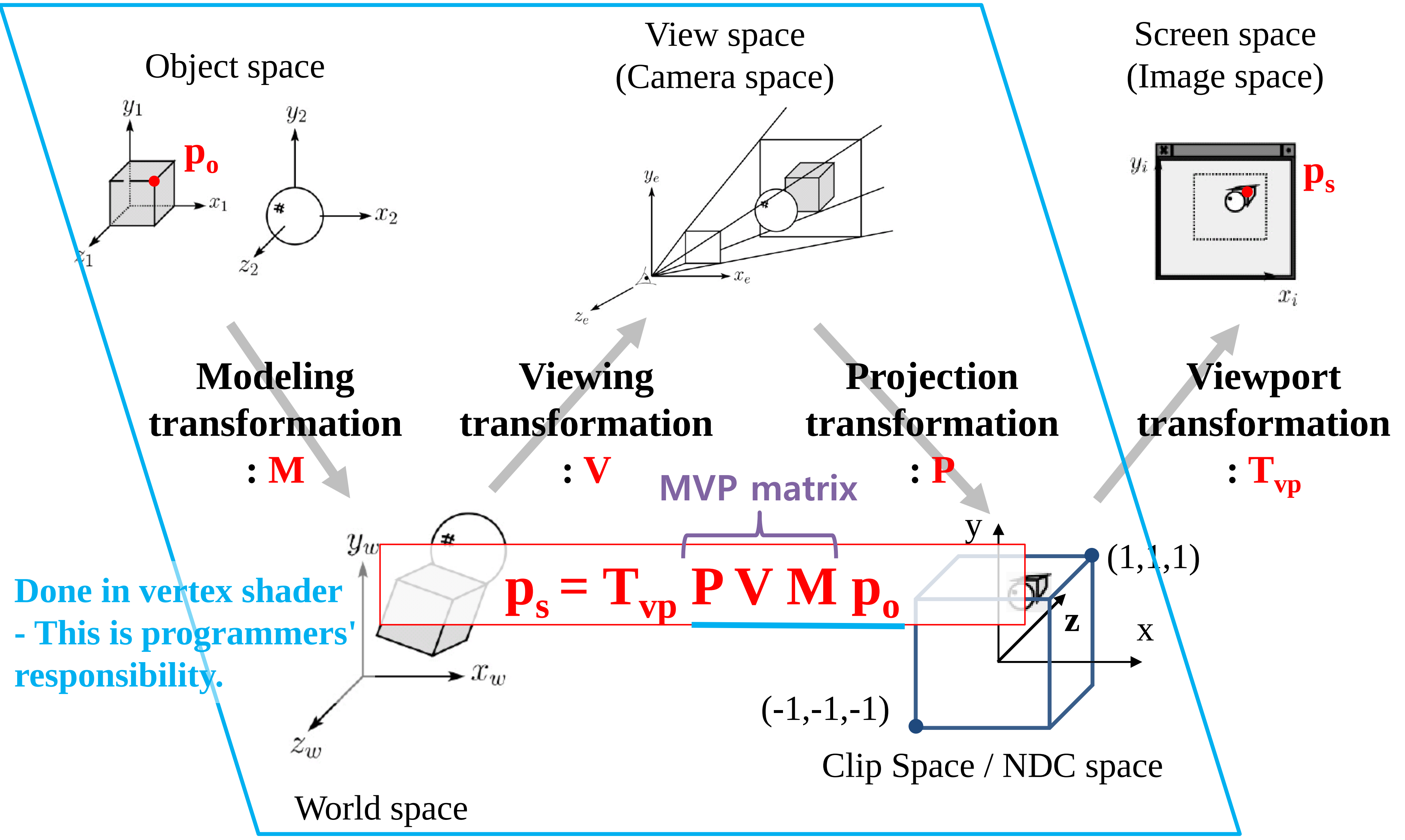
- Go to https://www.slido.com/
- Join #**cg-ys**
- Click "Polls"

- Submit your answer in the following format:
  - **Student ID: Your answer**
  - **e.g. 2021123456: 4.0**

- Note that your quiz answer must be submitted **in the above format** to receive a quiz score!

Viewport Transformation - glViewPort()

Recall: Vertex Processing in OpenGL



Modeling transformation : M

Viewing transformation : V

Projection transformation : P

Viewport transformation : T_{vp}

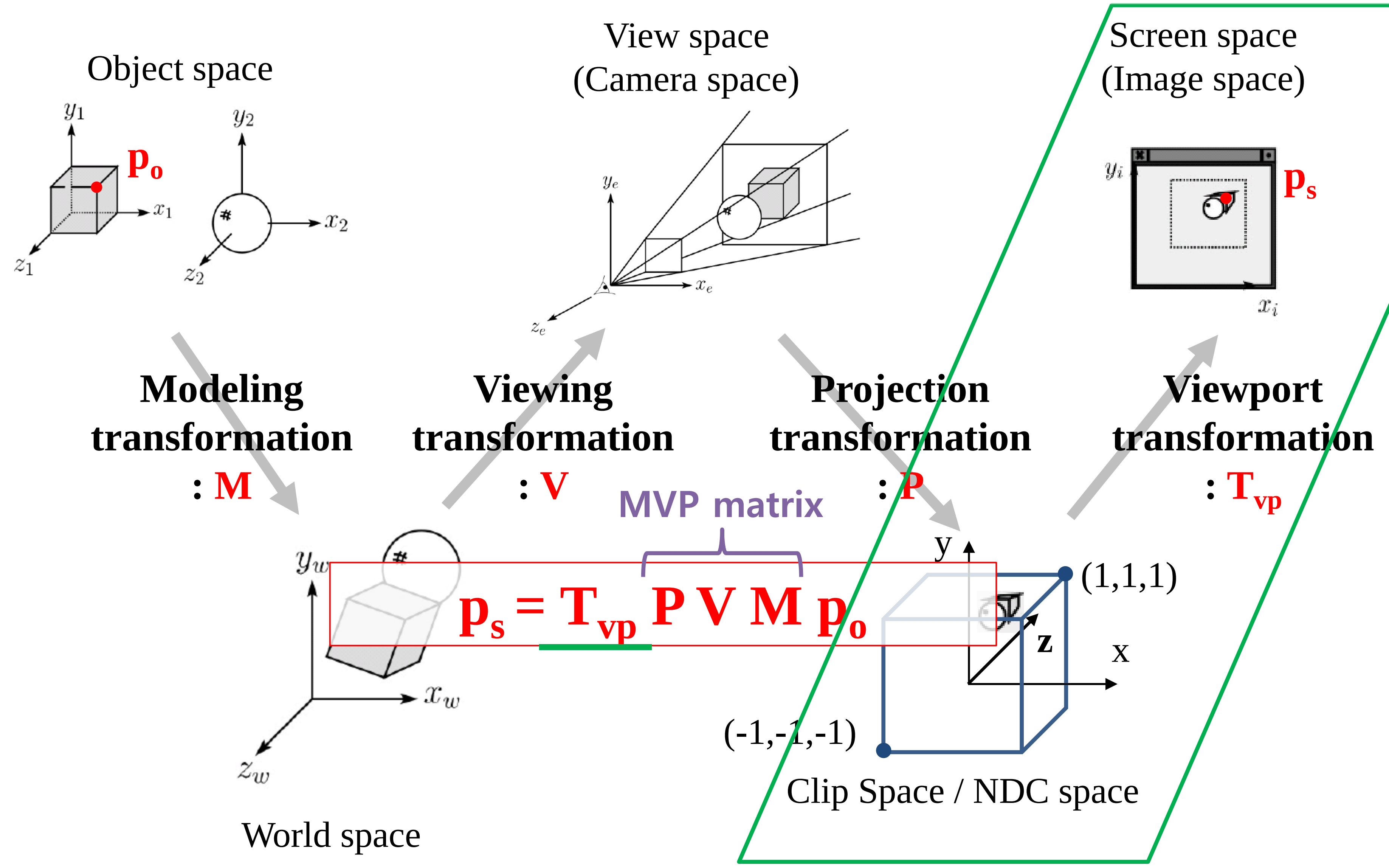
MVP matrix

$$\mathbf{p_s} = \mathbf{T_{vp}} \underbrace{\mathbf{P\,V\,M}}_{} \mathbf{p_o}$$

Done in vertex shader
- This is programmers' responsibility.

Vertex Processing in OpenGL

Done internally - Programmers just configure this with glViewPort()



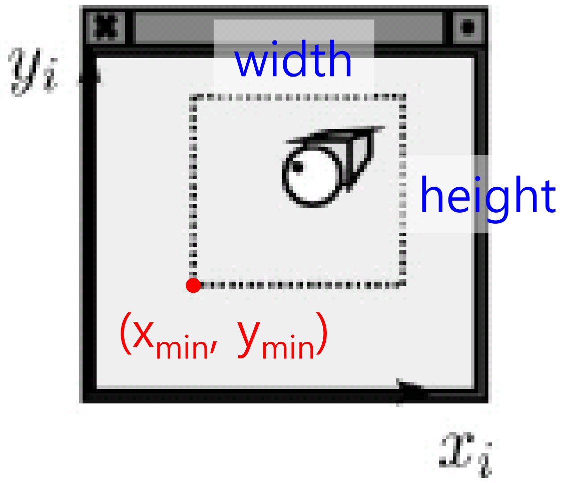
$$\mathbf{p_s} = \mathbf{T_{vp}} \underbrace{\mathbf{P\,V\,M}}_{\text{MVP matrix}} \mathbf{p_o}$$

glViewport()

- glViewport(xmin, ymin, width, height)
  - xmin, ymin, width, height: specified **in pixels**

- : Sets the viewport

- Default viewport setting for (xmin, ymin, width, height) is **(0, 0, window width, window height).**
  - If you do not call glViewport(), OpenGL uses this default viewport setting.



[Code] 3-viewport

```
def main():
    ...
    glViewport(100,100, 200,200)

    # loop until the user closes the window
    while not glfwWindowShouldClose(window):
    ...
```

Resizing Viewport to Fit to Window

- In the previous example, even if you resize the window, the viewport size remains the same.

- How can we make the viewport always fill the window even when the window is resized?

[Code]4-viewport-fit

```
def framebuffer_size_callback(window, width, height):
    glViewport(0, 0, width, height)

def main():
    ...
    # comment out
    # glViewport(100,100, 200,200)
    ...
    glfwSetFramebufferSizeCallback(window,
framebuffer_size_callback)
    ...
```

Maintaining Aspect Ratio When Resizing Viewport

- In the previous example, resizing the viewport also changes the aspect ratio of an object.

- How to ensure that the aspect ratio of an object is always maintained?

[Code] 5-viewport-fit-preserve-objratio-ortho

```
# now projection matrix P is a global variable so that it can be accessed
from main() and framebuffer_size_callback()
g_P = glm.mat4()
...

def framebuffer_size_callback(window, width, height):
    global g_P

    glViewport(0, 0, width, height)

    ortho_height = 10.
    ortho_width = ortho_height * width/height
    g_P = glm.ortho(-ortho_width*.5,ortho_width*.5,
-ortho_height*.5,ortho_height*.5, -10,10)
```

[Code] 5-viewport-fit-preserve-objratio-ortho

```
def main():
    global g_P
    ...
    # initialize projection matrix
    ortho_height = 10.
    ortho_width = ortho_height * 800/800    # initial width/height
    g_P = glm.ortho(-ortho_width*.5,ortho_width*.5, -
ortho_height*.5,ortho_height*.5, -10,10)

    while not glfwWindowShouldClose(window):
        ...

        # draw world frame
        draw_frame(vao_frame, g_P*V*glm.mat4(), MVP_loc)

        ...

        # # draw cube w.r.t. the current frame MVP
        # draw_cube(vao_cube, g_P*V*M, MVP_loc)

        # draw cube array w.r.t. the current frame MVP
        draw_cube_array(vao_cube, g_P*V*M, MVP_loc)
```

Time for Assignment

- Let's start today's assignment.
- TA will guide you.