Rendering

Part 1
An introduction to OpenGL

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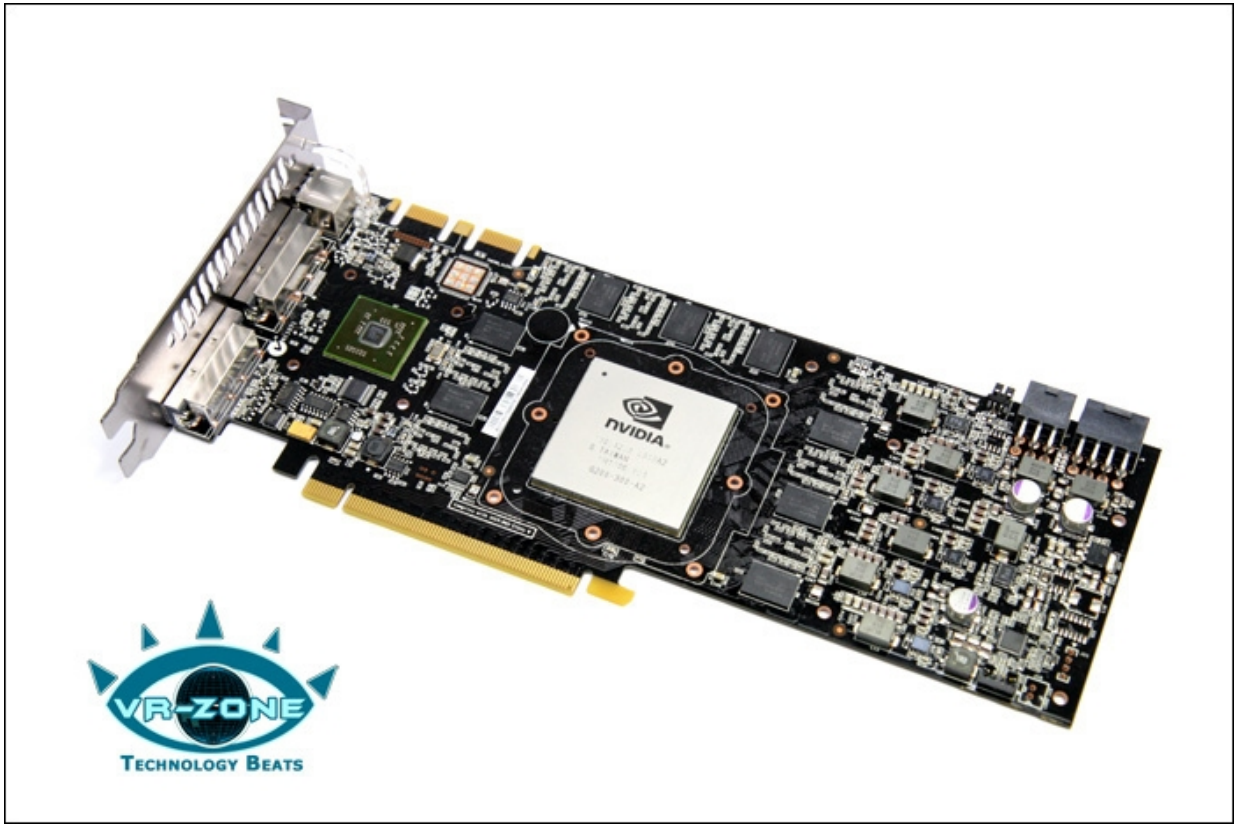
VORTEX

Image synthesis

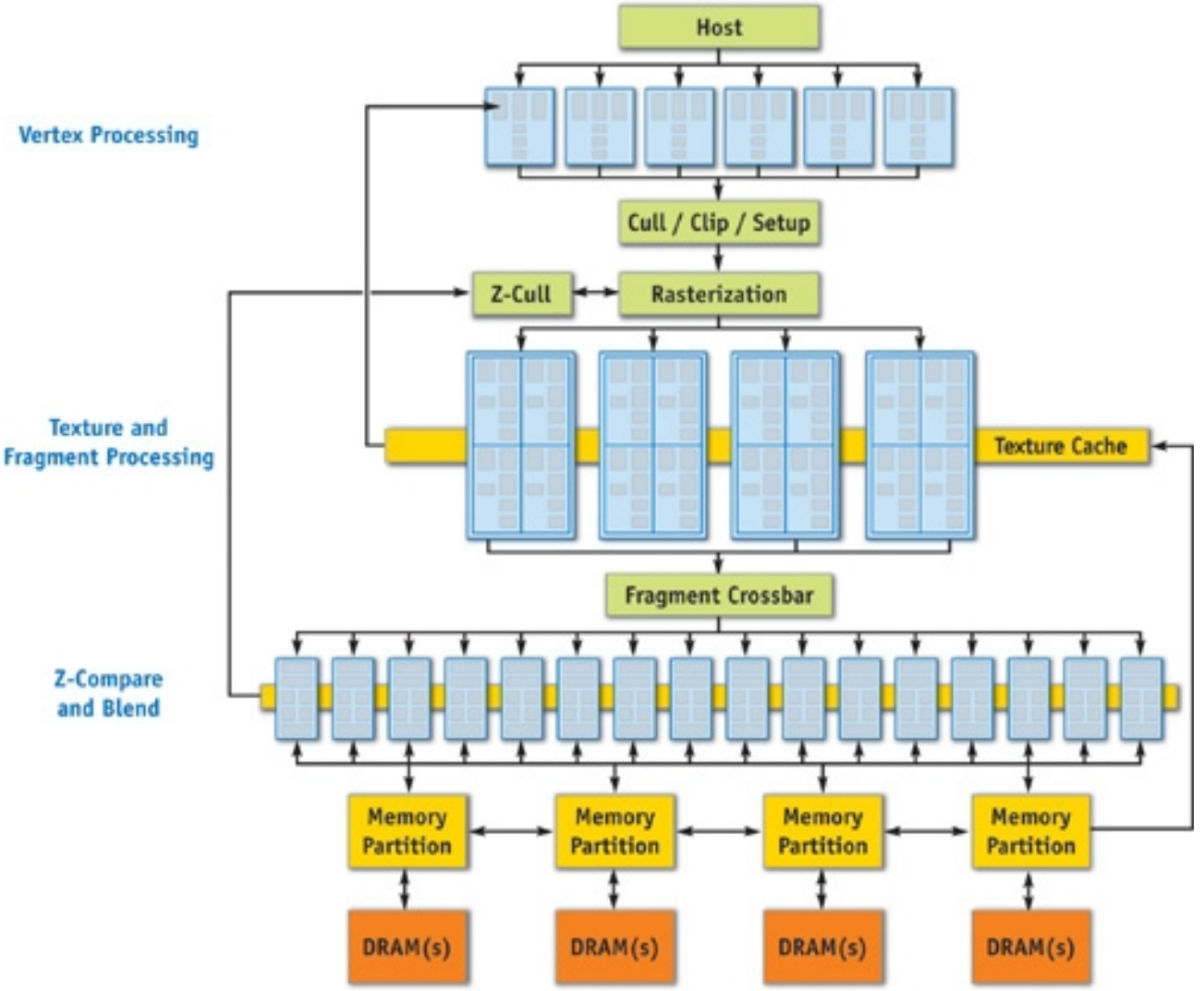
The Graphics Processing Unit (GPU):

- A highly parallel architecture specialized in the rasterization of objects composed of polygons (meshes), usually triangles.



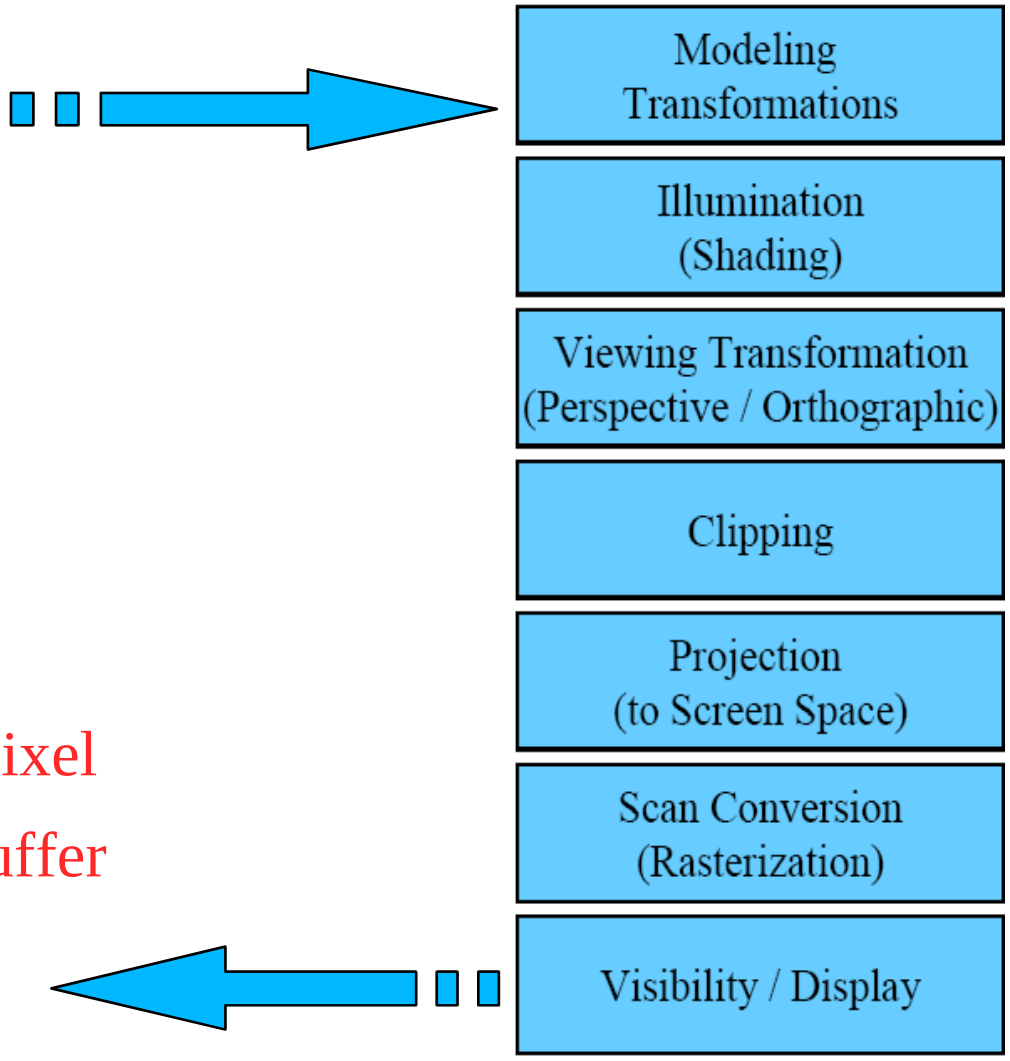
The GPU

- Architecture of a GPU (nVidia GeForce 6800)



The graphic pipeline

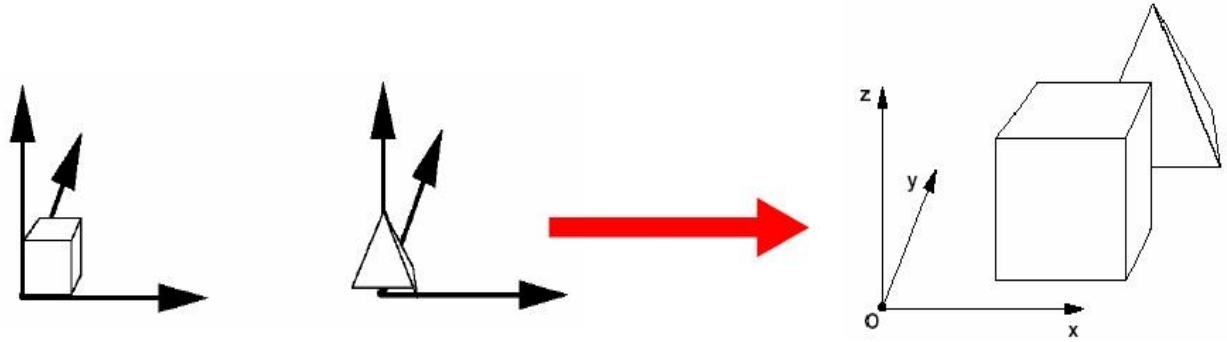
- Input:
  - Geometry
  - Lighting model
  - Camera Model
  - Output area



- Output:
  - Color value at each pixel
  - Stored in the framebuffer

The graphic pipeline

- 3D Objects:
  - Defined in their own frame (object space)
  - The object frame is located in the world space (with regards to world frame)



Modeling Transformations

Illumination (Shading)

Viewing Transformation (Perspective / Orthographic)

Clipping

Projection (to Screen Space)

Scan Conversion (Rasterization)

Visibility / Display

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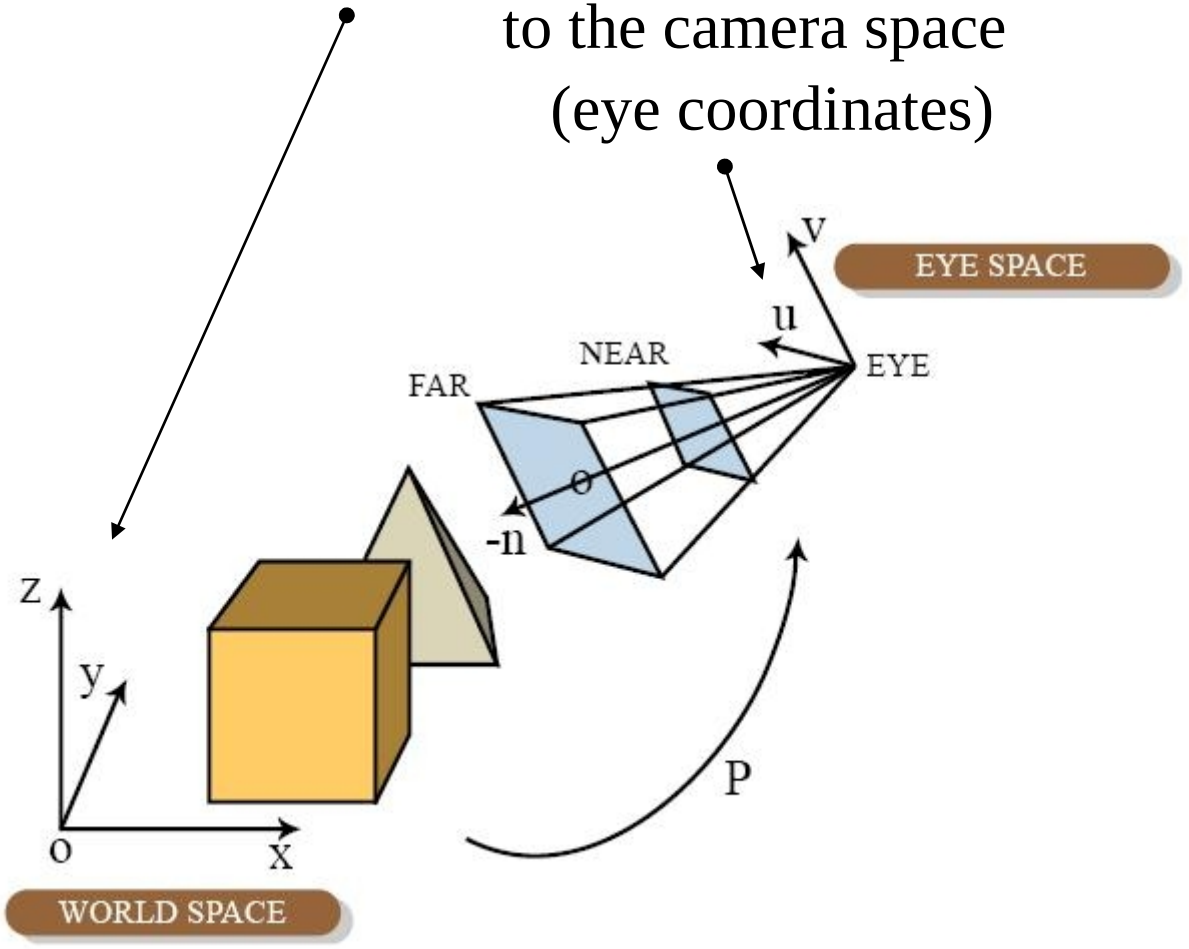
The graphic pipeline

Transforms vertex coordinates
from the world space

to the camera space
(eye coordinates)



- Modeling Transformations
- Illumination (Shading)
- **Viewing Transformation (Perspective / Orthographic)**
- Clipping
- Projection (to Screen Space)
- Scan Conversion (Rasterization)
- Visibility / Display

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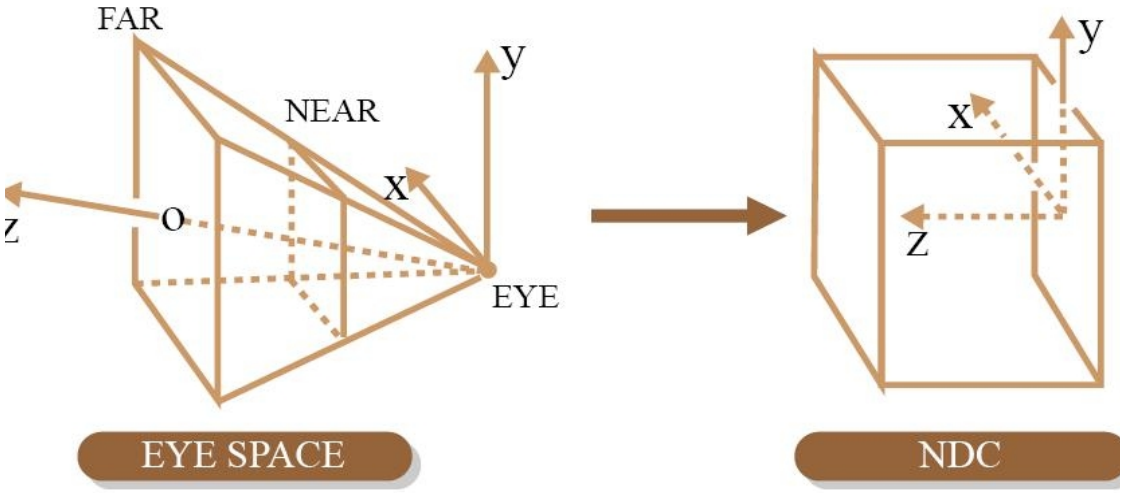
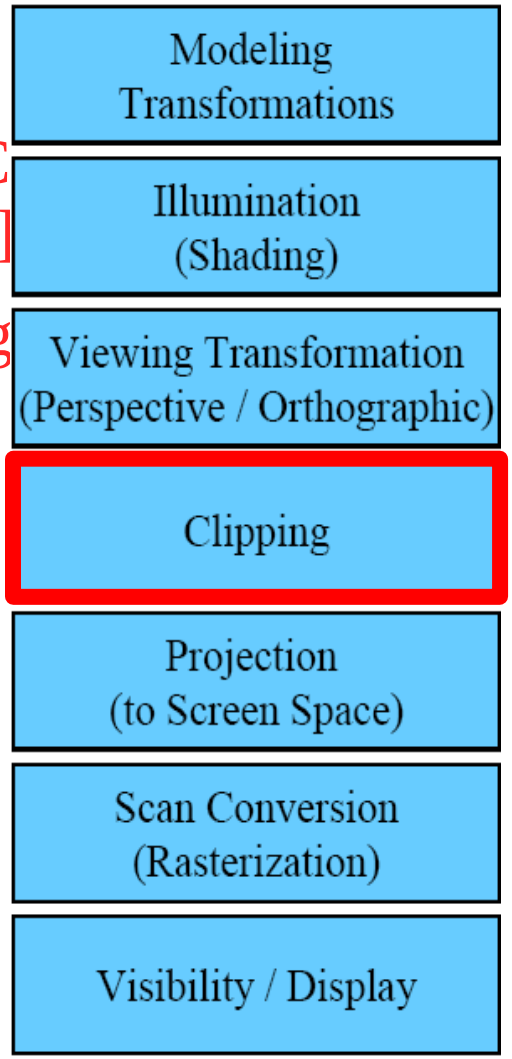
The graphic pipeline

- Clipping :
  - Transforms eye coordinates to Normalized Device Coordinates (NDC) (maps each coordinates to range [-1, 1]
  - Suppresses geometry outside the viewing volume





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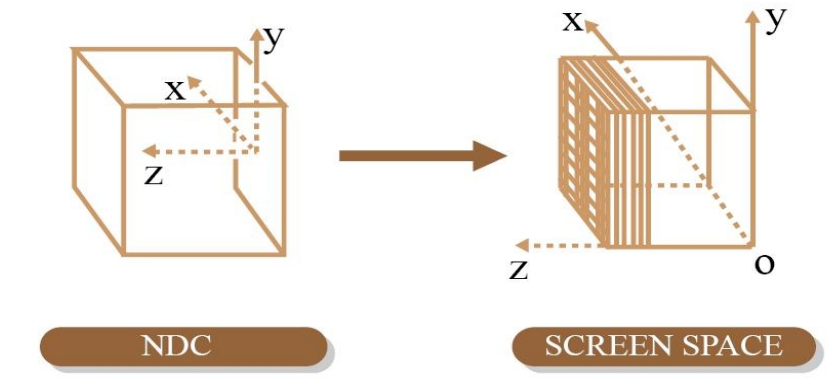
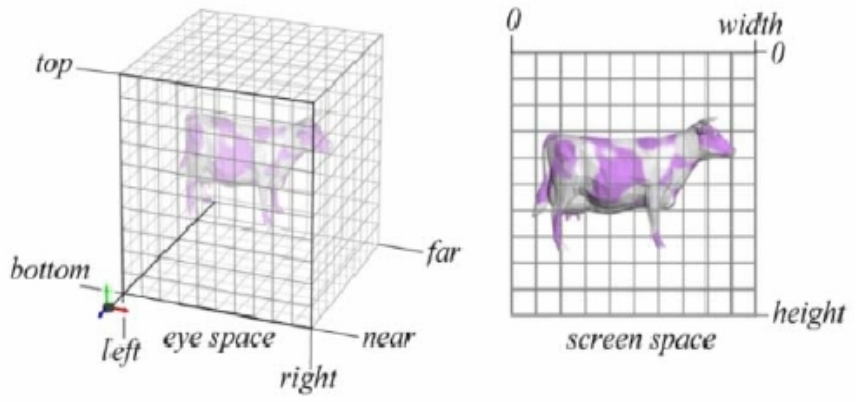
The graphic pipeline

- Projection to screen space (2D) :





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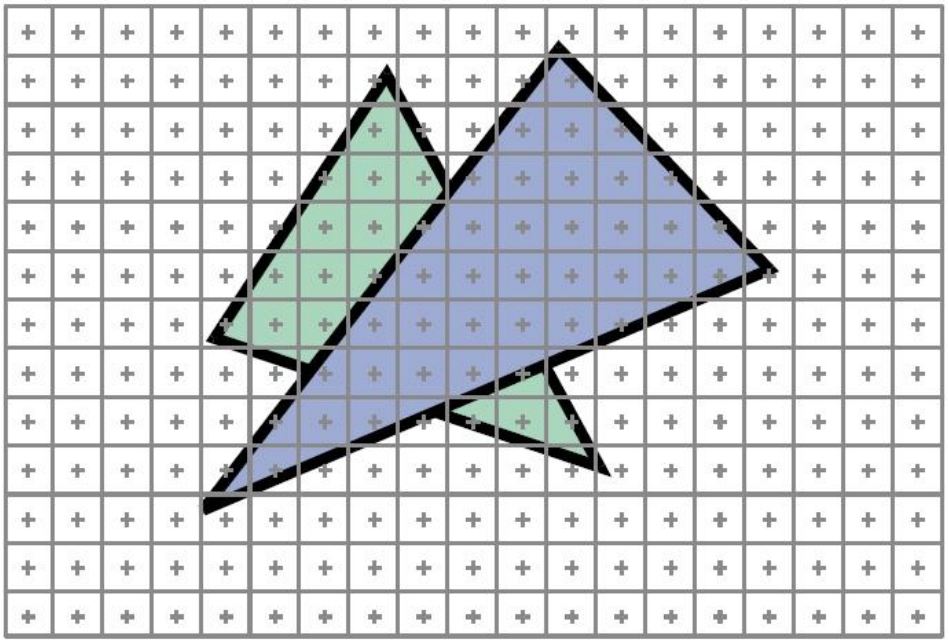
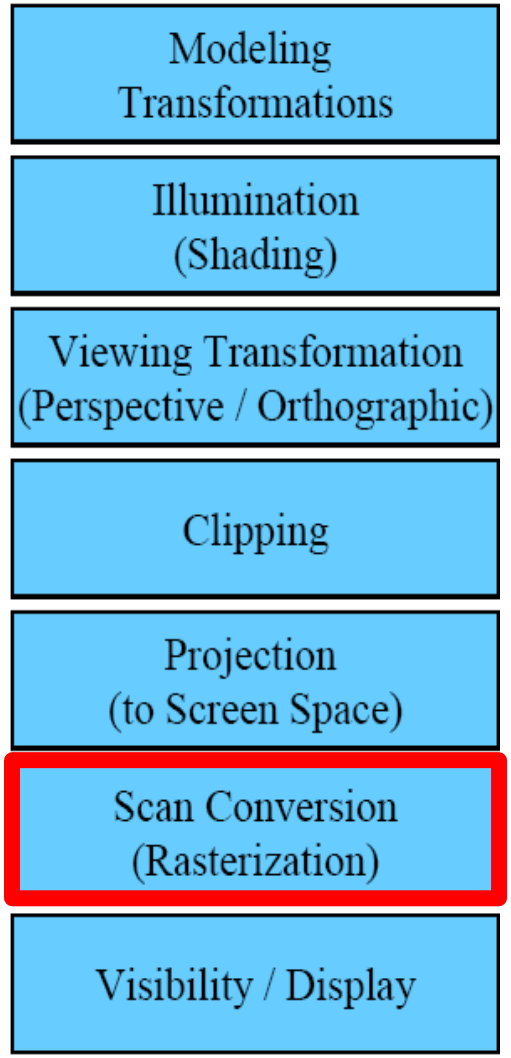
The graphic pipeline

- Rasterization : for each triangle
  - Computes the pixels overlapped by this triangle (fragments)
  - Interpolates the vertex attributes (color, normals, depth...) at each fragment

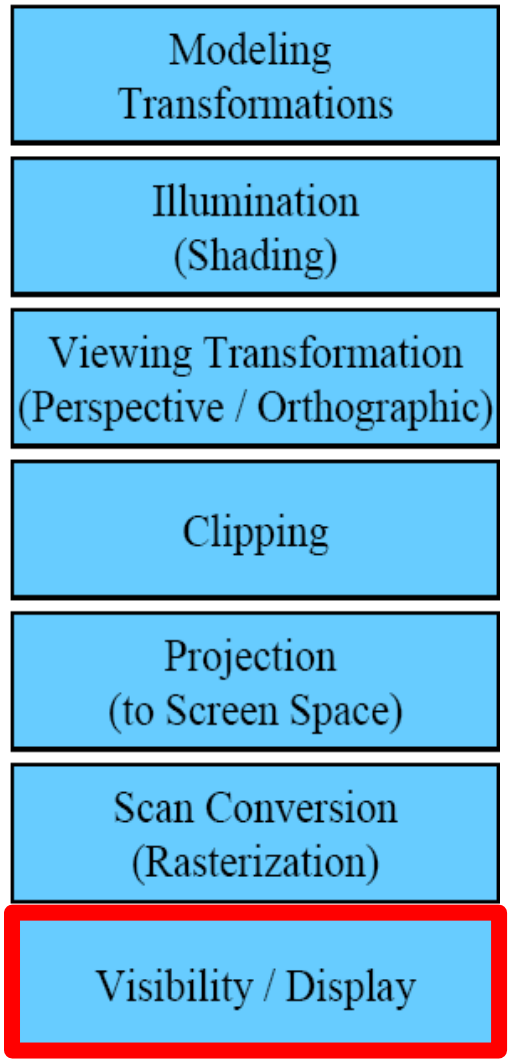




The graphic pipeline

- Eliminates hidden fragments using a *depth buffer*

- A depth buffer stores the depth of the last fragment written at each pixel.



The graphic pipeline

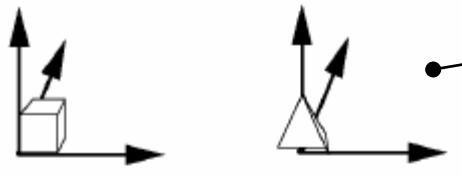
Object space

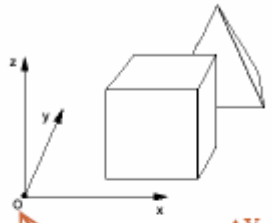
World space

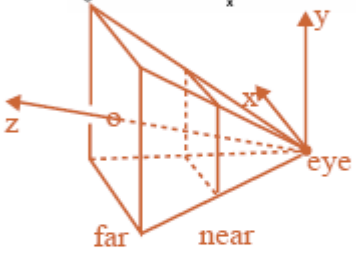
Eye space

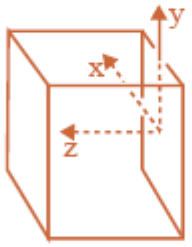
Normalized device coordinates

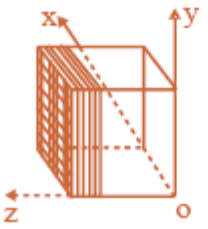
Screen space











Modeling Transformations

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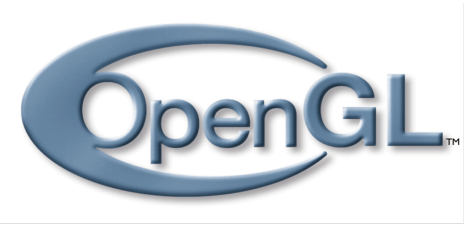
Introduction to OpenGL

- OpenGL : Open Graphics Library
  - Standard specification (Architecture Review Board (ARB))
  - API : software interface with graphic hardware
    - 200 commands to write interactive 3D programs
  - State machine
    - State variables : viewing frustum, drawing color, material properties, light properties, etc.

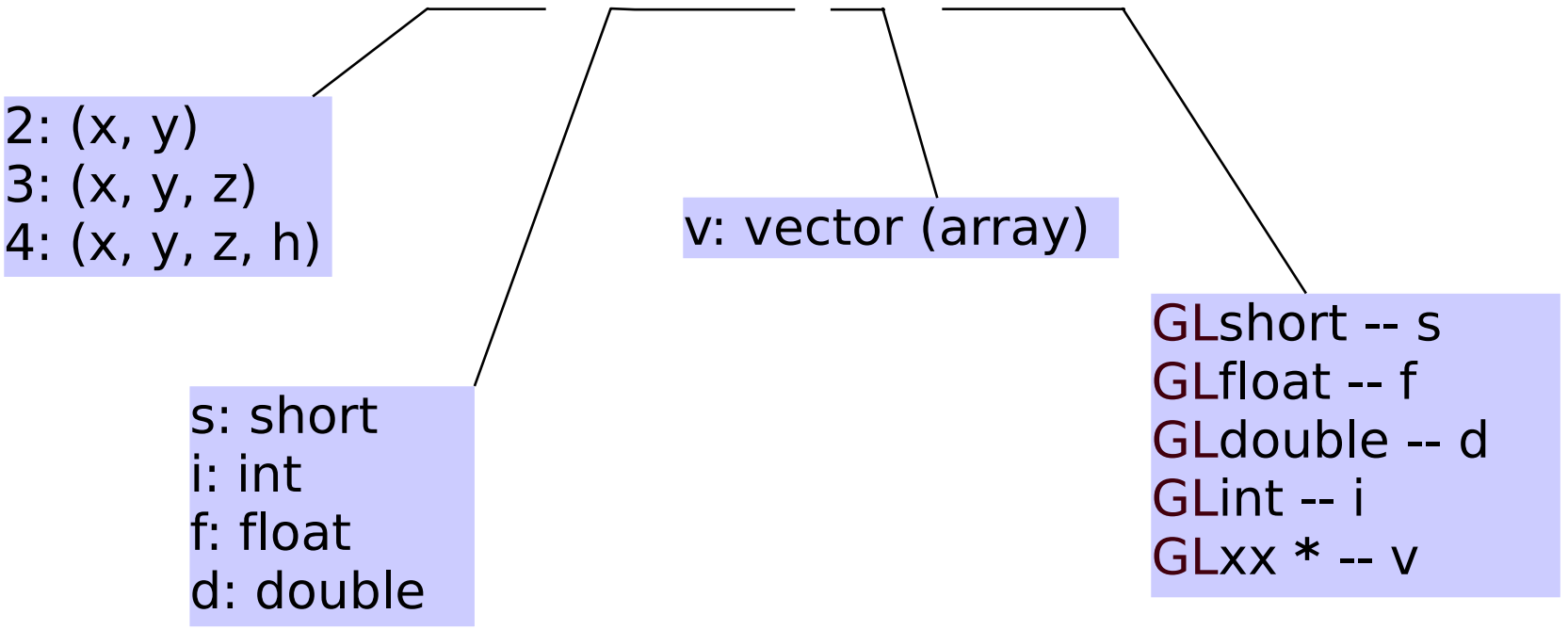
- OpenGL is not
  - A window manager
  - A 3D modeling tool



Basic commands

- General form of an OpenGL function:

```
void gl...{2,3,4}{s,i,f,d}[v] (TYPE coords);
```



Basic commands

- Vertex: basic component of a primitive

  glVertex {2,3}{s,i,f,d}[v]()

  - Defined between a glBegin() and a glEnd()
  - Specification of a mode (type of the primitive)

```
glBegin(mode);
glVertex*(coordinates);
glVertex*(coordinates);
.
.
glVertex*(coordinates);
glEnd();
```

MODES
GL_POINTS
GL_LINES
GL_LINE_STRIP
GL_LINE_LOOP
GL_POLYGON
GL_TRIANGLES
GL_TRIANGLE_STRIP
GL_TRIANGLE_FAN
GL_QUADS
GL_QUAD_STRIP

Basic commands

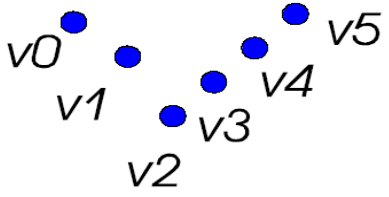
- glVertex* (coordinates)
  Samples:

```
glVertex2s(2, 3);
glVertex3d(0.0, 0.0, 3.1415926535898);
glVertex3f( 2.3f, 12.0f, -4.8f);

GLdouble dvect[3]={5.0, 9.0, 1435.0};
glVertex3dv(dvect);
```

```
typedef struct {
    GLfloat x, y, z;
} Point3D;

Point3D pt = {0.0, 4.0, 6.0};
glVertex3fv((GLfloat *) &pt);
```

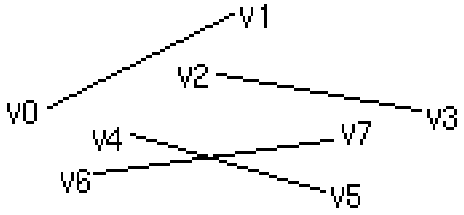
Basic commands

- Primitive types:
  - Points

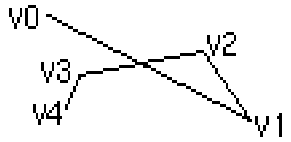


GL_POINTS

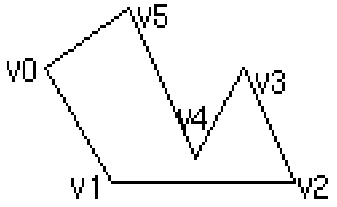
  - Line segments
    - Independent line segments
    - Polylines
    - Empty polygons



GL_LINES



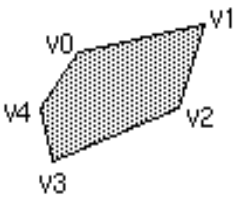
GL_LINE_STRIP



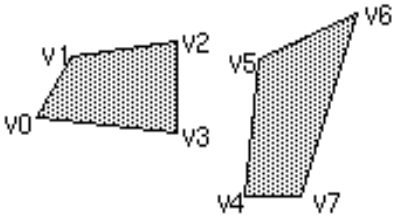
GL_LINE_LOOP

Basic operations

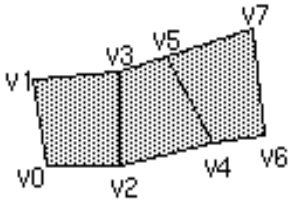
- Primitive types
  - Filled polygons
    - polygons, independent triangles or quads
    - triangle fan, triangle strip, quad strip



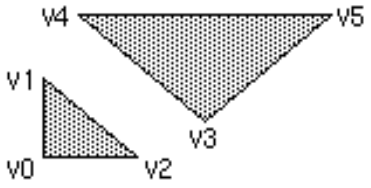
GL_POLYGON



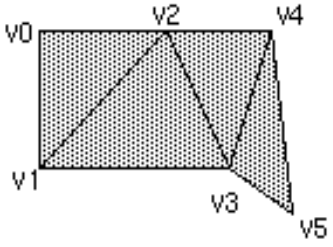
GL_QUADS



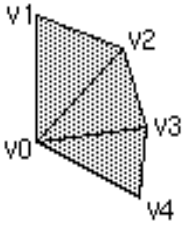
GL_QUAD_STRIP



GL_TRIANGLES



GL_TRIANGLE_STRIP



GL_TRIANGLE_FAN

Basic operations

- Polygons orientation
  - Default : front face if oriented counterclockwise on the screen
  - Can be changed :

glFrontFace(mode)

    - Mode : GL_CCW (counterclockwise), GL_CW (clockwise)

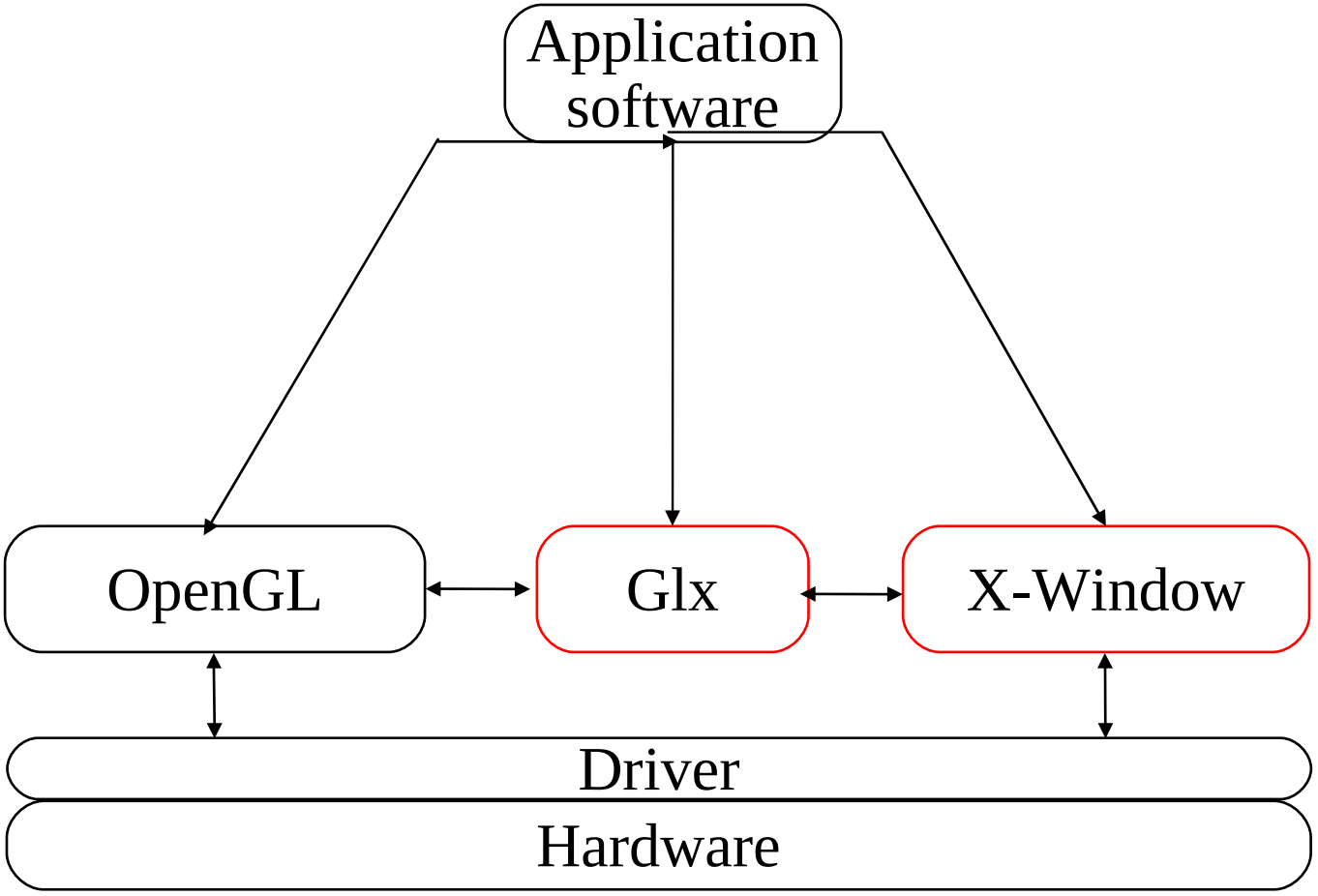
- Drawing mode of the faces

glPolygonMode(face, mode)

  - Face : GL_FRONT, GL_BACK, GL_FRONT_AND_BACK
  - Mode : GL_POINT, GL_LINE, GL_FILL

Introduction to OpenGL

- Programming interfaces



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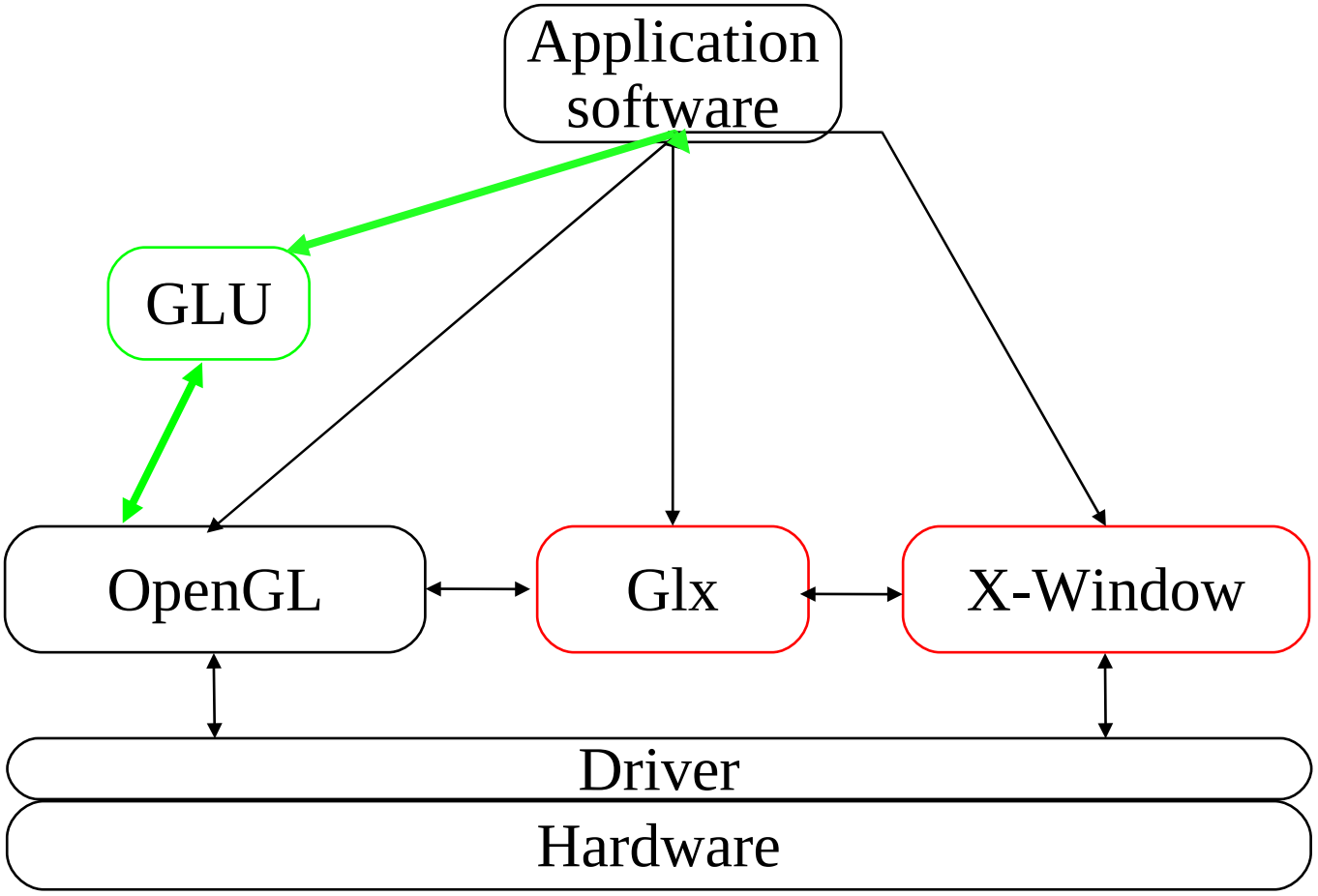
Introduction to OpenGL

- Programming interfaces



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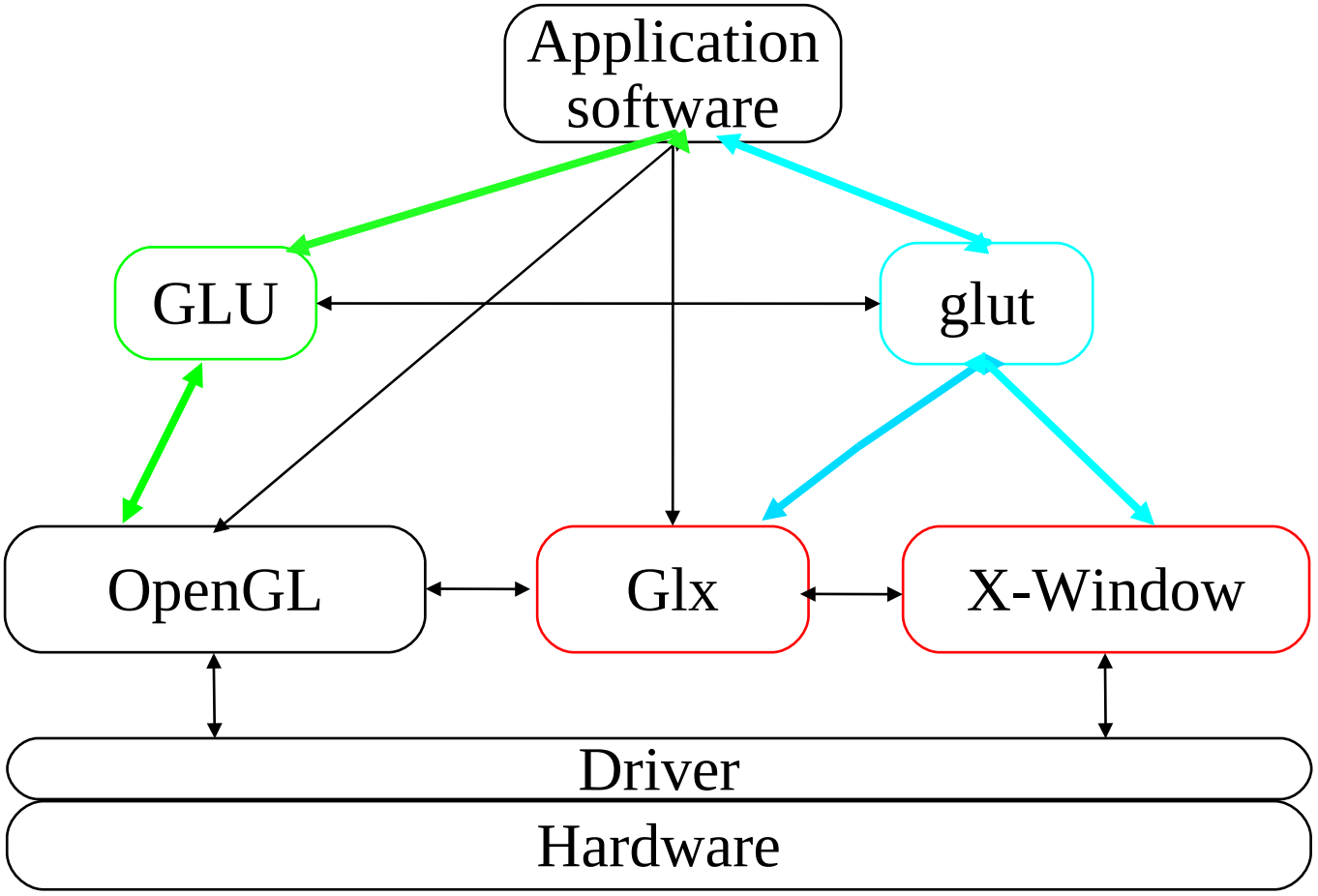
Introduction to OpenGL

- Programming interfaces



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Introduction to GLUT

- GL Utility Toolkit (≠ OpenGL)
  - A library to create and handle windows easily
  - Can be used to handle events as well (key strokes, etc..)
  - Available on various platforms
    - Linux, Windows, MacOS ...

Introduction to GLUT

- Initializing and creating windows
  - Just call the functions :
    - void glutInit(int * argc, char **argv);
    - void glutInitDisplayMode(unsigned int mode);
    - void glutInitWindowSize(int width, int height);
    - void glutInitWindowPosition(int x, int y);
- Then :
    - int glutCreateWindow(char *title);

Introduction to GLUT

- Can be used to handle double buffering
  - void glutSwapBuffers(void);
- Can be used to redraw the window at any time
  - void glutPostRedisplay(void);
- (At last) launch the main loop (waits for an event)
  - void glutMainLoop(void);

Introduction to GLUT

- Handles user interactions
  - with the use of Callback procedures:
  - void glutDisplayFunc(void (*f)(void));
  - void glutReshapeFunc(void (*f)(int width, int height));
  - void glutKeyboardFunc(void (*f)(unsigned int key, int x, int y));
  - void glutMouseFunc(void (*f)(int button, int state, int x, int y));
  - void glutMotionFunc(void (*f)(int x, int y));
  - void glutSpecialFunc(void (*f)(int key, int x, int y));
  - void glutIdleFunc(void (*f) (void));

Introduction to GLUT

- GLUT has some predefined 3D objects:
  - void glut{Wire Solid}Cube(GLdouble size);
  - void glut{Wire Solid}Sphere(GLdouble radius, GLint slices, GLint stacks);
  - void glut{Wire Solid}Cone(GLdouble base, GLdouble height, GLint slices, GLint stacks);
  - void glut {Wire Solid}Torus(GLdouble innerRadius, GLdouble outerRadius, GLint nsides, GLint rings);
  - void glut {Wire Solid}Teapot(GLdouble size);
  - void glut {Wire Solid}Tetrahedron(void);
  - void glut {Wire Solid}Decahedron(void);

Tutorial: Draw a simple polygon

- Write an OpenGL program that draws a filled polygon in white on a black background
  - Function that draws the polygon
    - void display(void)
  - Function that quits the application whenever <q> is stroked
    - void key (unsigned char c, int mouseX, int mouseY)
  - Function handling the possible change in size of the window
    - void reshape(int width, int height)
  - Main
  - Include and constants