Computer Graphics

Introduction

Course Info

- Text Book:

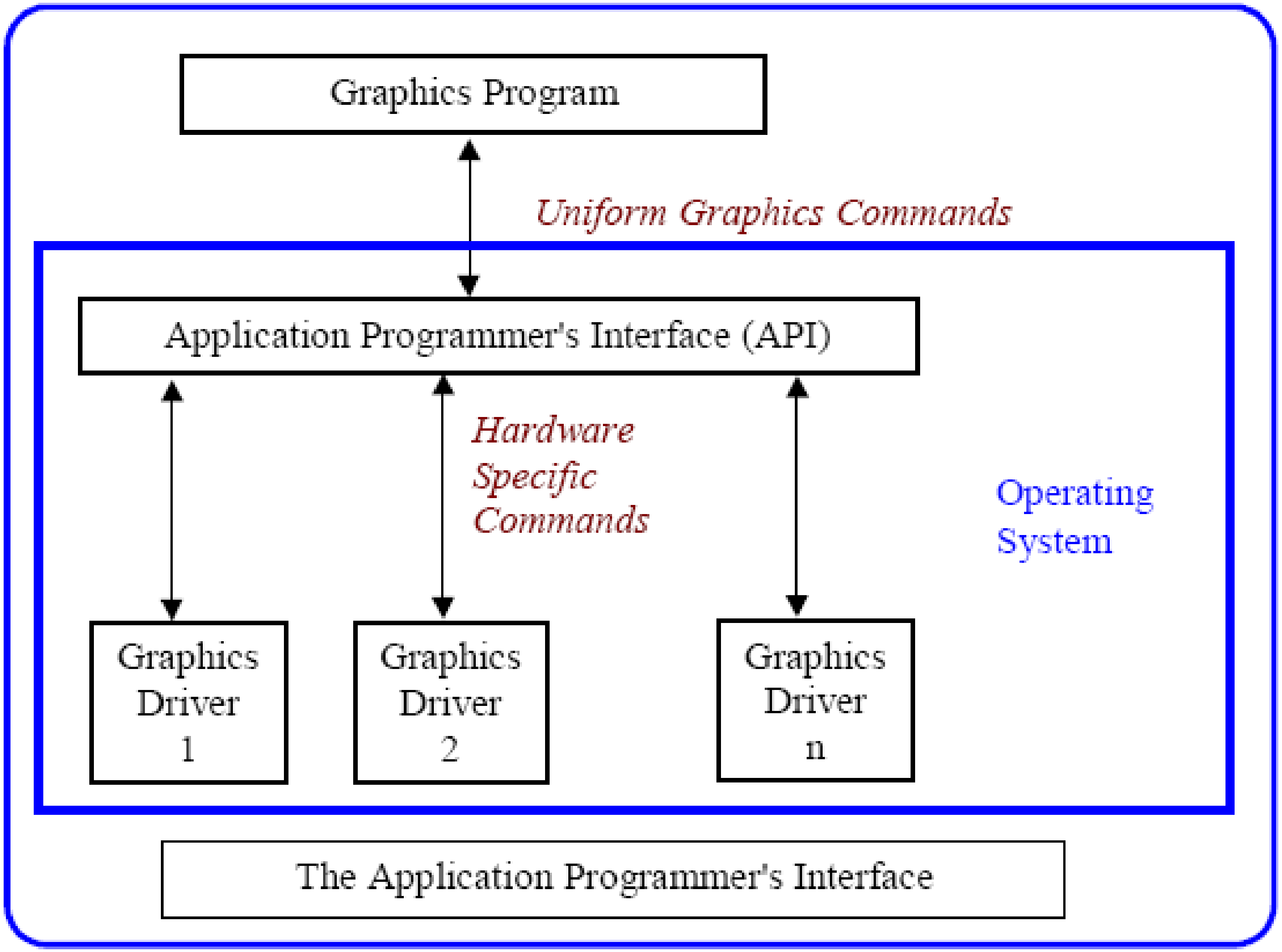
  Computer Graphics using OpenGL, F.S.Hill

  Computer Graphics C Version, Donald Hearn, Pauline Baker, Prentice-Hall
- Evaluation
  - Final exam (%40)
  - Programming assignments (20%)
  - Final project (40%)

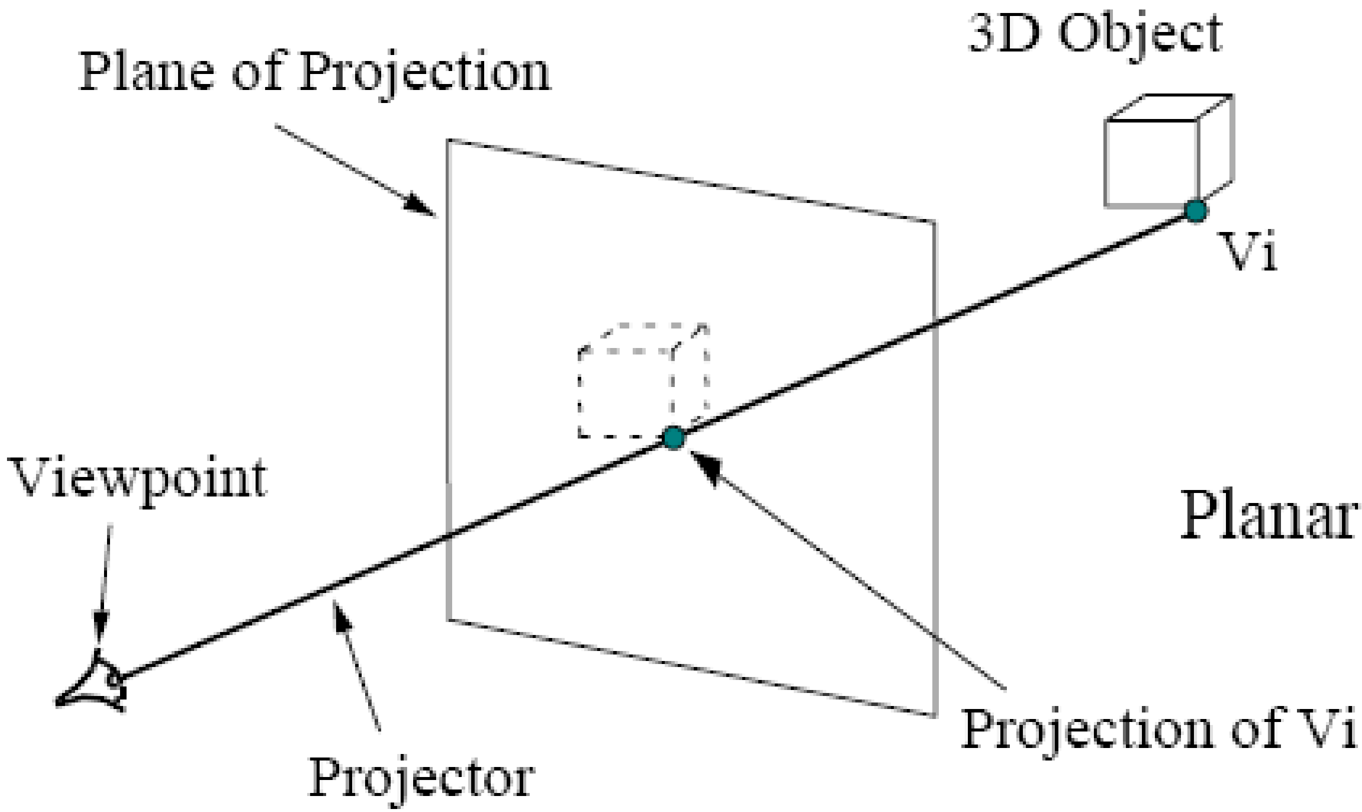
Course Outline

- Device independent graphics: Raster and Vector Devices, Normalized Device Coordinates,
- World Coordinates, The Normalization Transformation, Output primitives, Input Primitives.
- Projection and Transformation: 3D Planar objects, projection to 2D, Homogenous coordinates, scene transformation
- Clipping and containment in 3D convex objects, splitting concave objects.
- Texture mapping and anti-aliasing.
- Polygon Rendering and Open GL
- Using Colors: Tri-stimulus model, RGB model, YCM model, Perceptual color spaces.
- Shading planar polygons: Gouraud Shading, Phong Shading.
- Ray Tracing: Ray/object intersection calculations Secondary rays, shadows, reflection and refraction. Computational efficiency, object space coherence, ray space coherence
- Radiosity: Modeling ambient light, form factors, specular effects, shooting patches, computational efficiency
- Scene Animation: Flying Sequences, object transformations
- Introduction to Spline curves, cubic spline patches and Bezier Curves
- Introduction to Surface Construction, Bezier Surfaces, the Coon's patch
- Geometric Warping and Morphing Objects

Device Independent Graphics

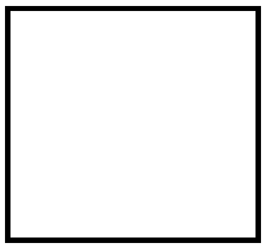


Projection

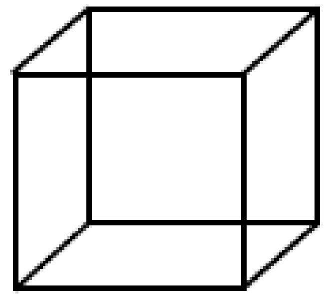


Planar projection

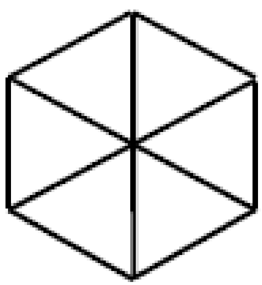
Orthogonal Projection



Looking at a Face



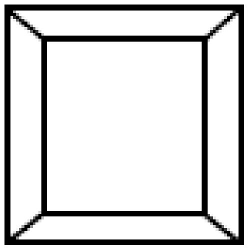
General View



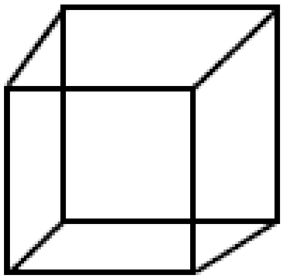
Looking at a vertex

Orthographic (parallel)
projection of a cube

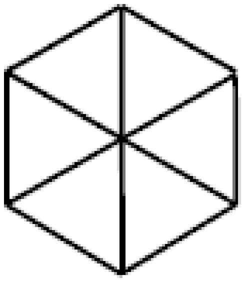
Perspective Projection



Looking at a Face



General View



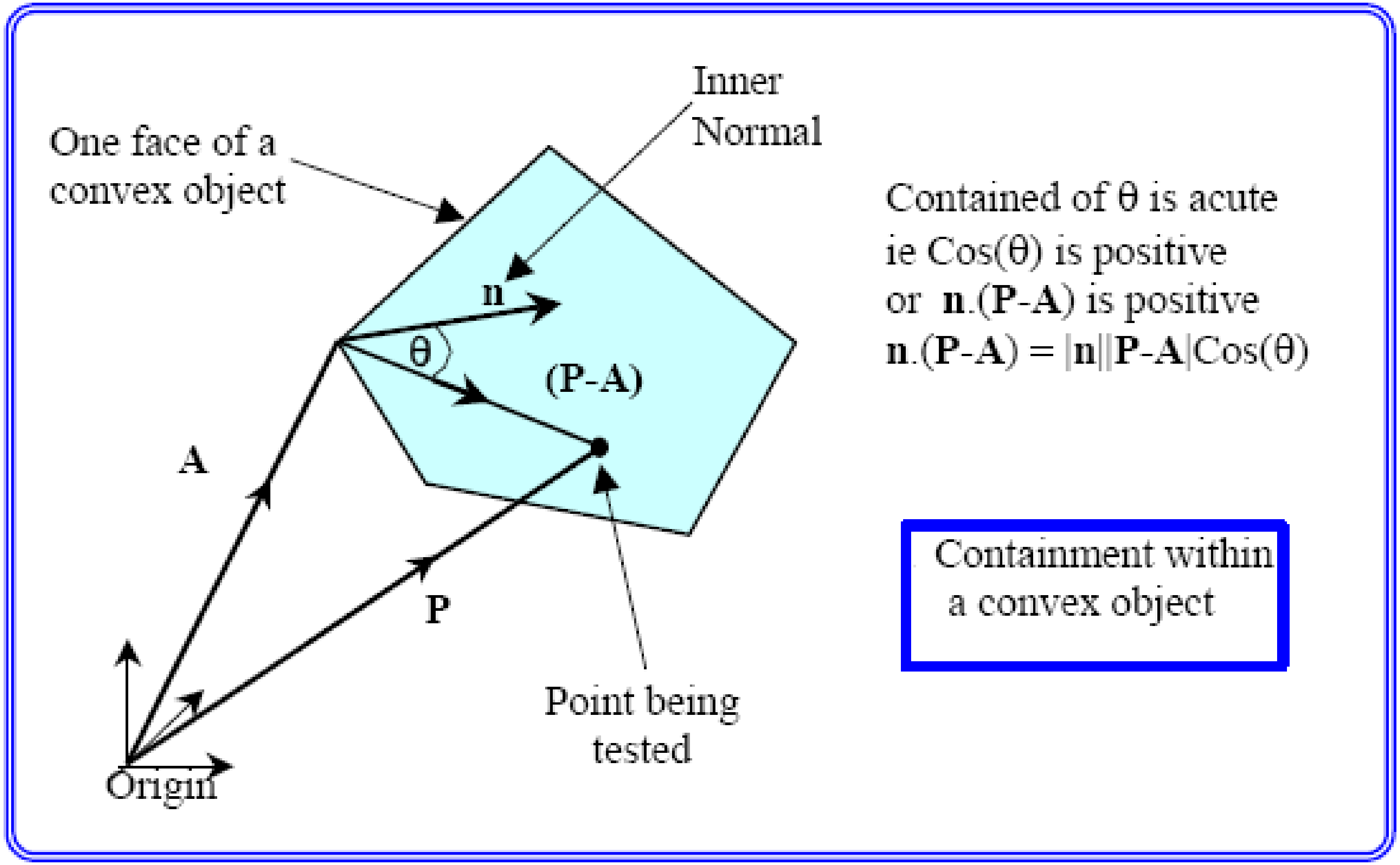
Looking at a vertex

Perspective projection of a cube

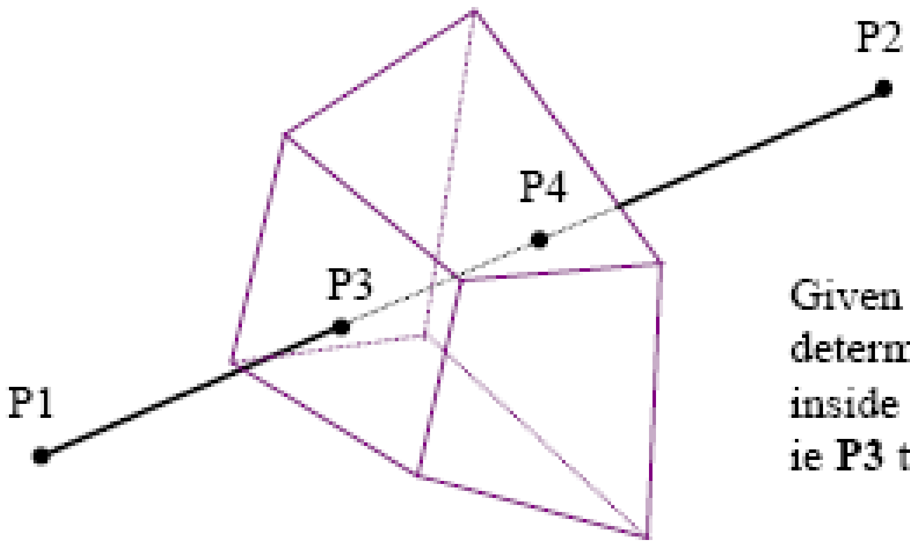
Containment and Clipping

- *Containment: checks to see if a* point is inside an object.
- *Clipping: determines where a line (or polygon) intersects an* object.

Containment



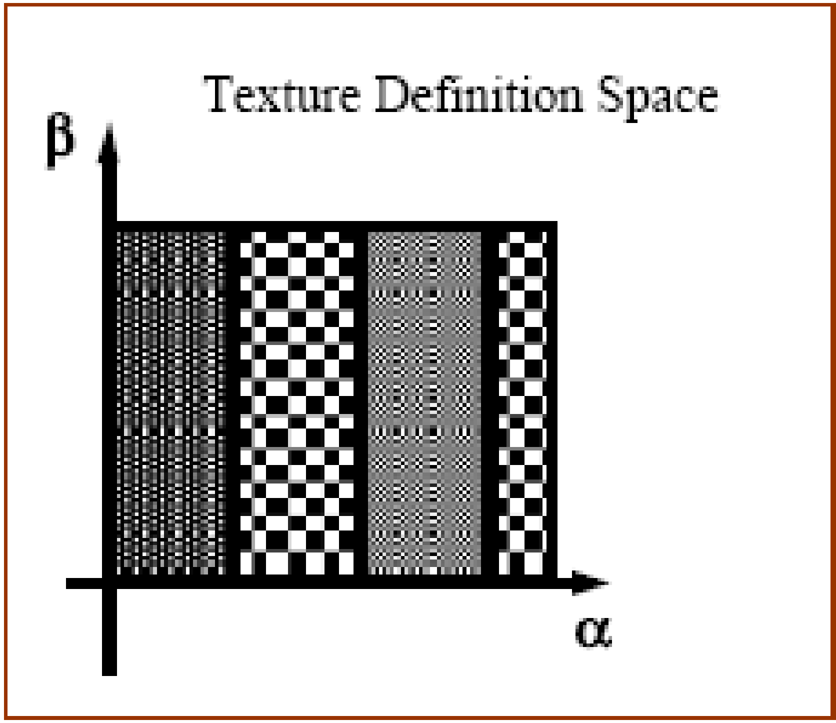
Clipping

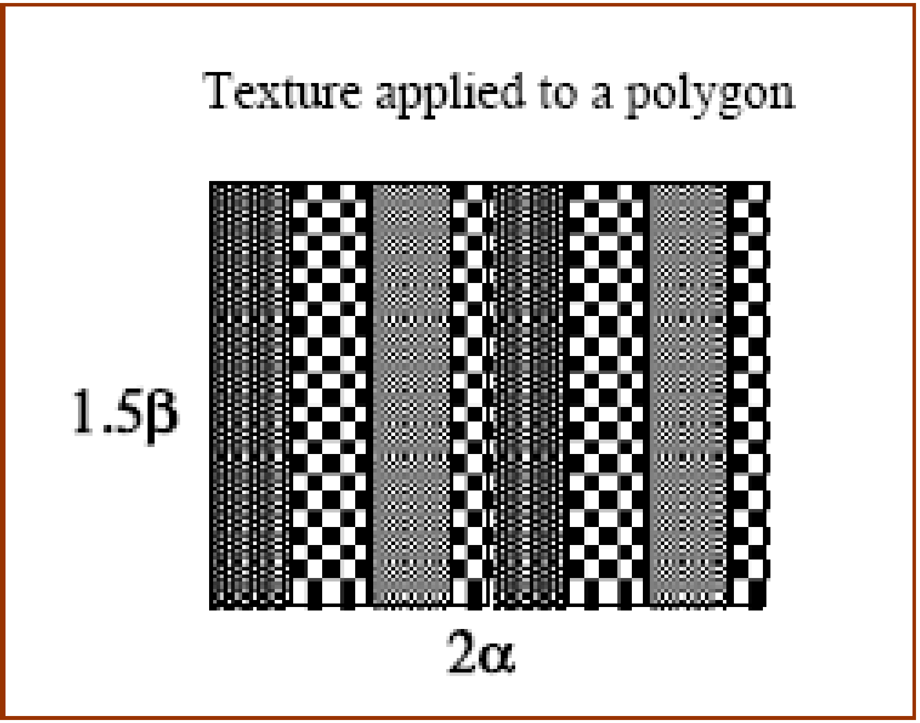


Given a line segment **P1** to **P2** determine the part of the line inside a convex object, ie **P3** to **P4**

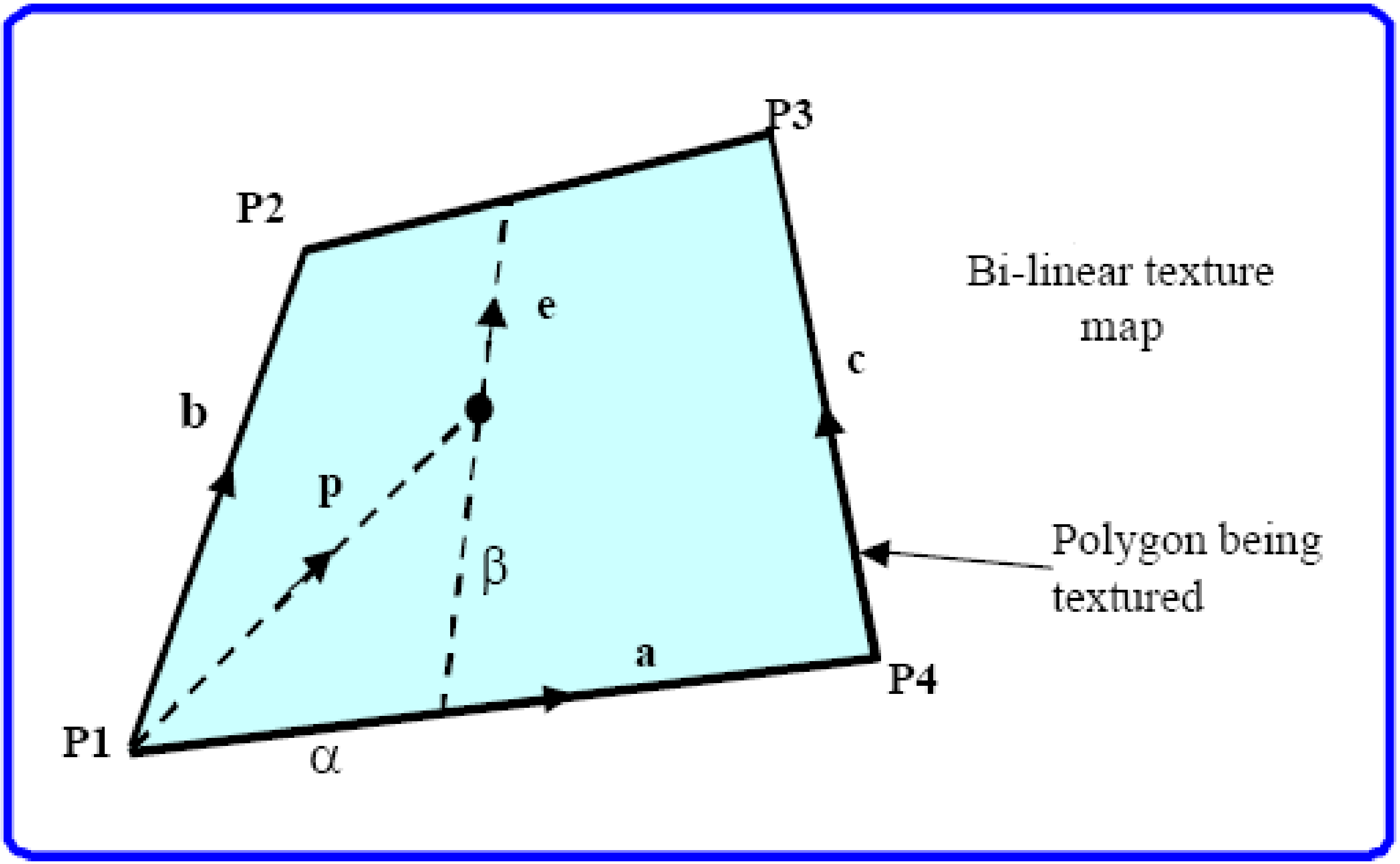
Clipping to a convex volume

Texture Mapping

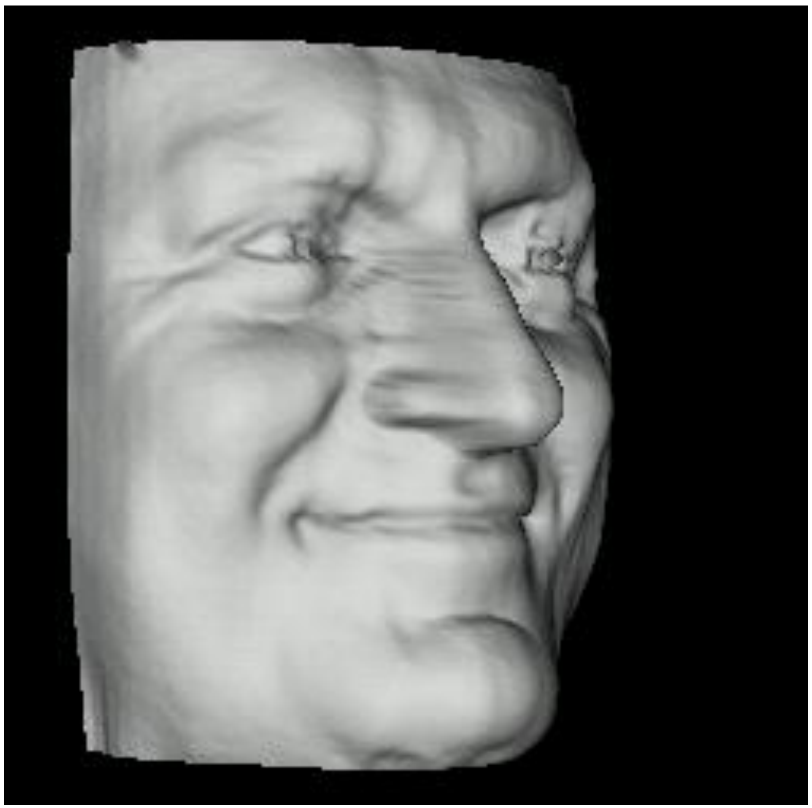




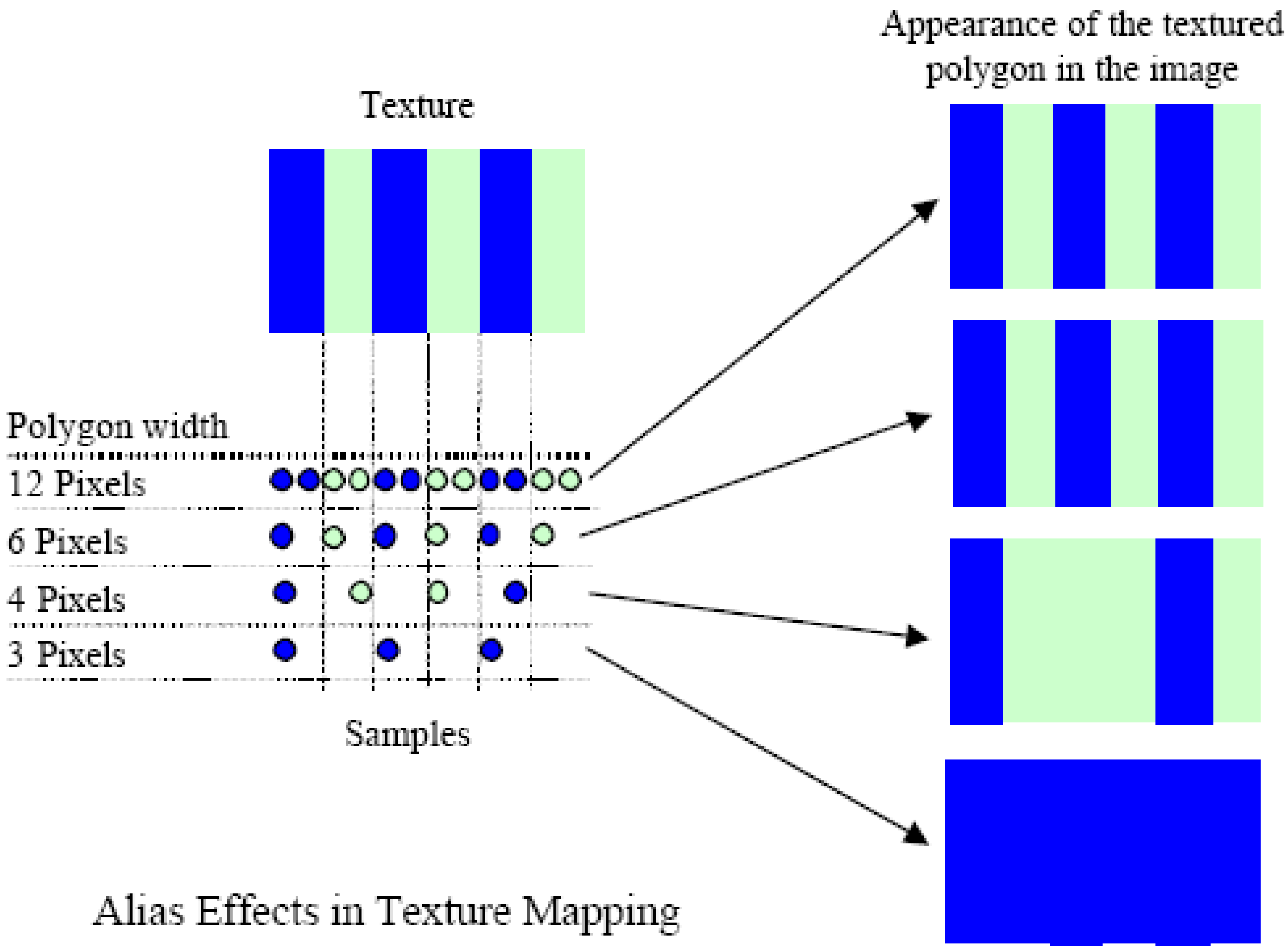
Texture Mapping



Texture Mapping

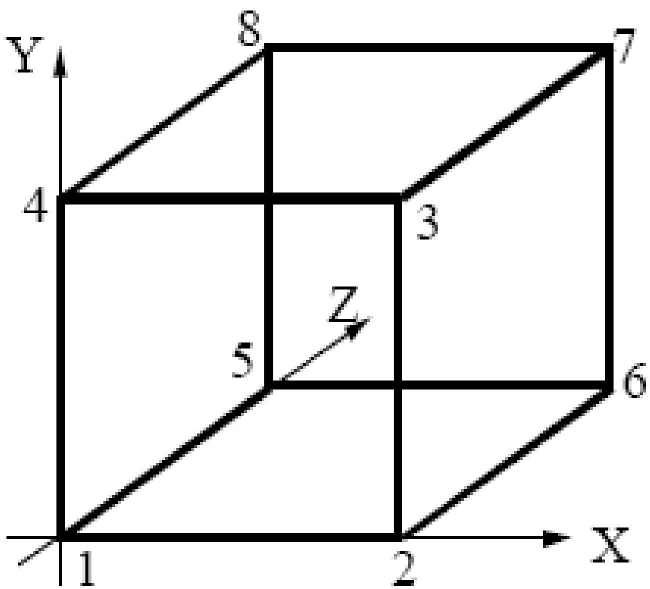


Anti-Aliasing



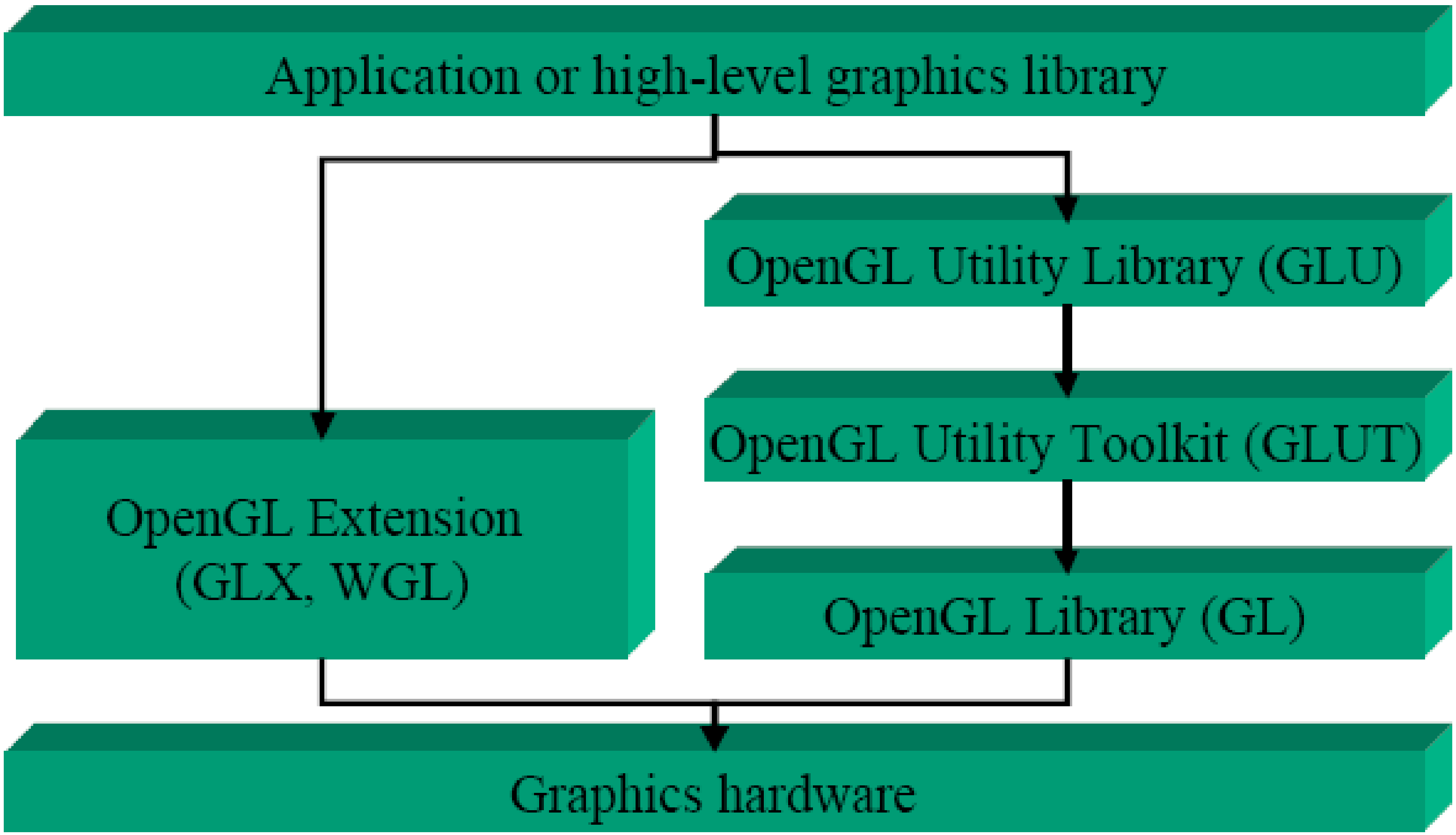
Alias Effects in Texture Mapping

Polygon Rendering and Open GL

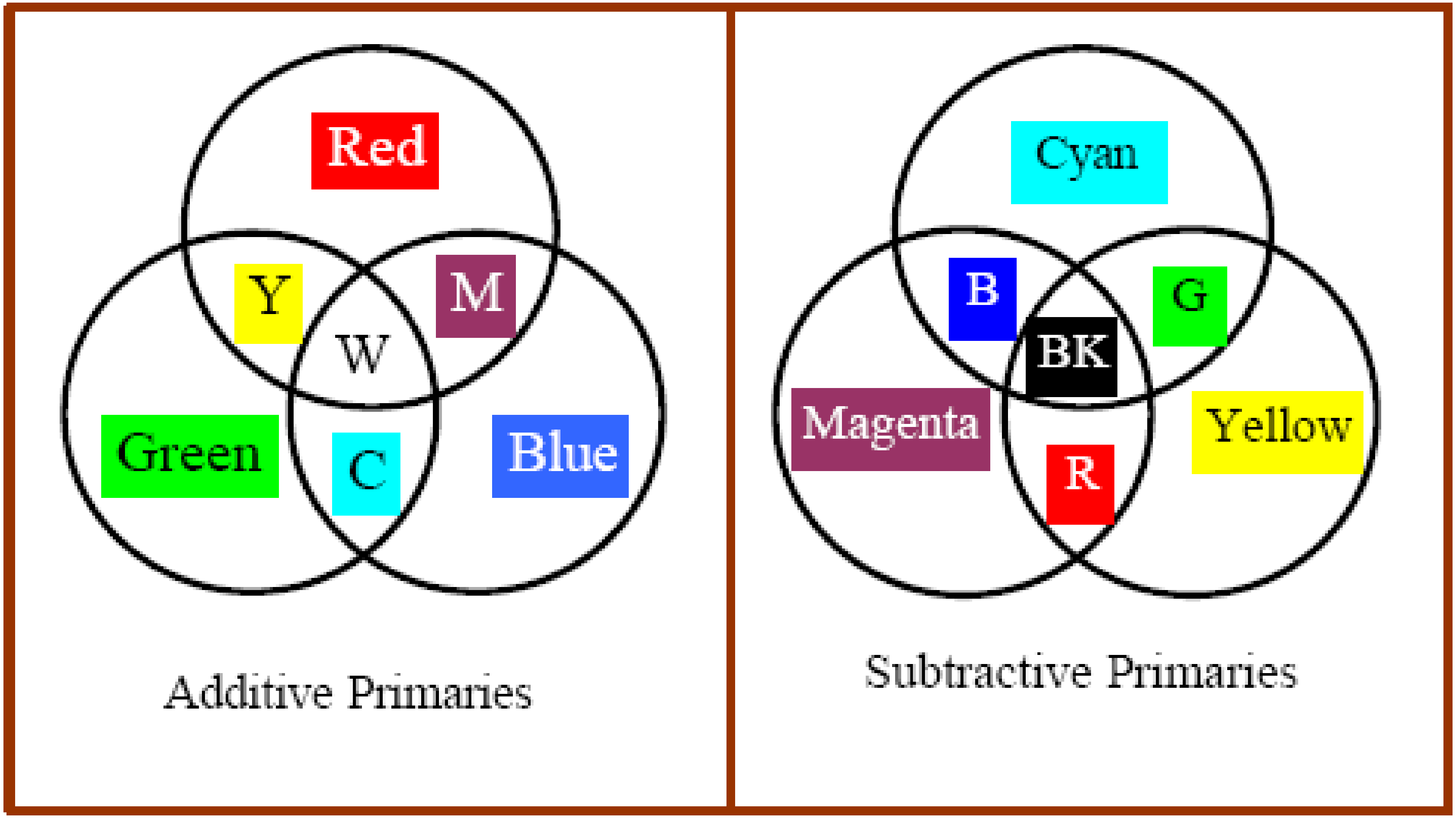


NUMERICAL DATA	TOPOLOGICAL DATA	
Points	Lines	Faces
1. [0,0,0] 2. [2,0,0] 3. [2,2,0] 4. [0,2,0] &c	1. 1>>2 2. 1>>4 3. 1>>5 4. 3>>4 5. 3>>2 &c	1,2,4,4 1,4,8,5 &c

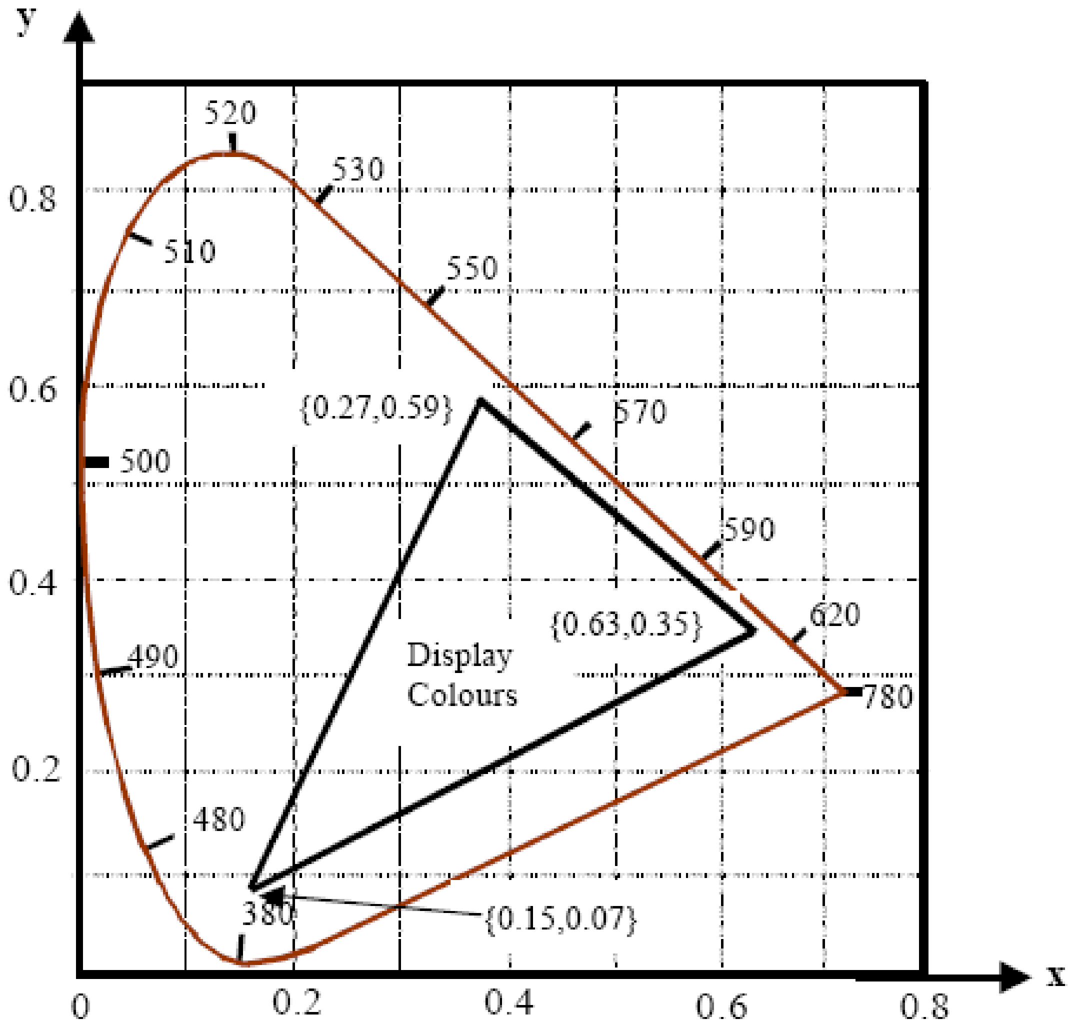
Polygon Rendering and Open GL



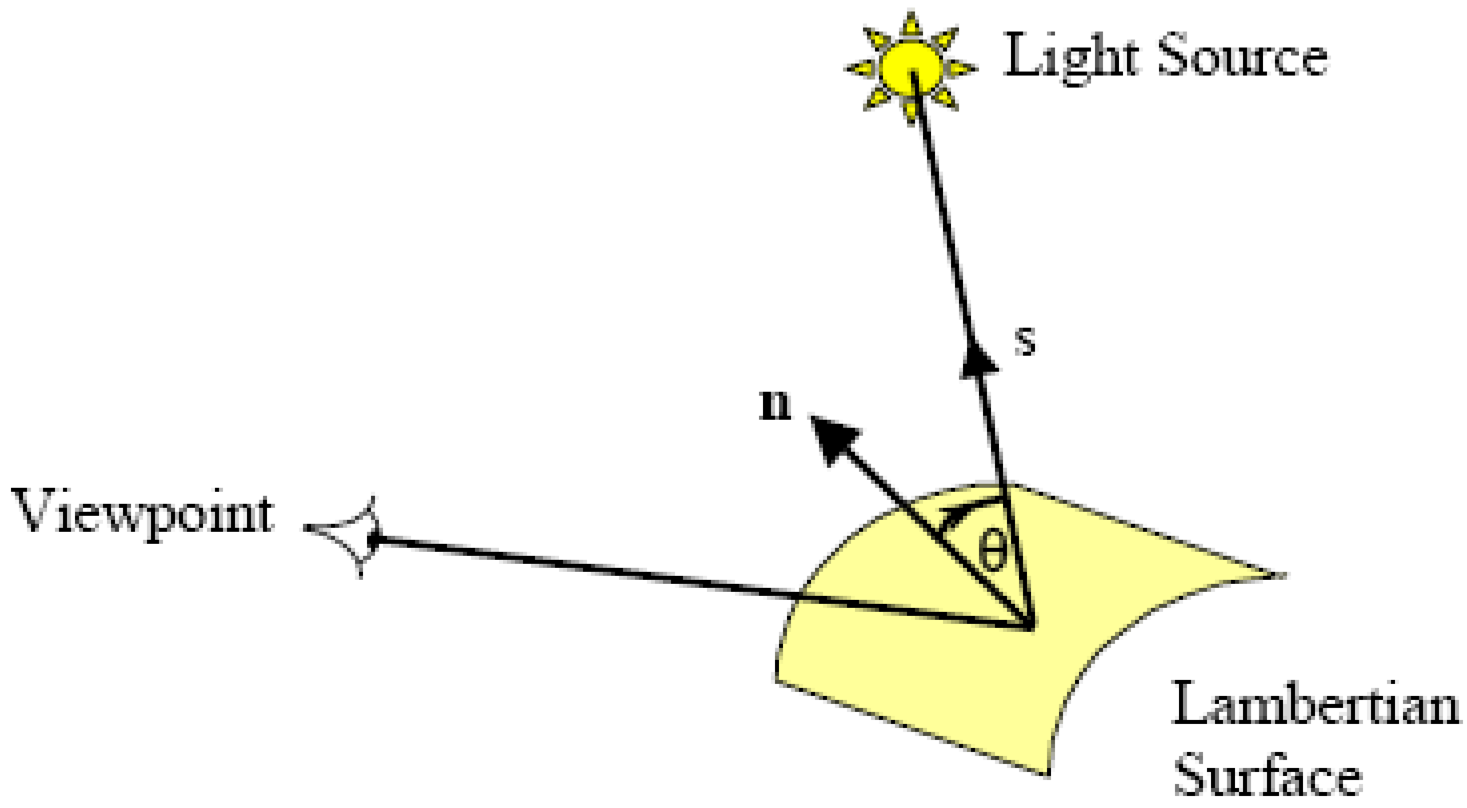
Using Colors



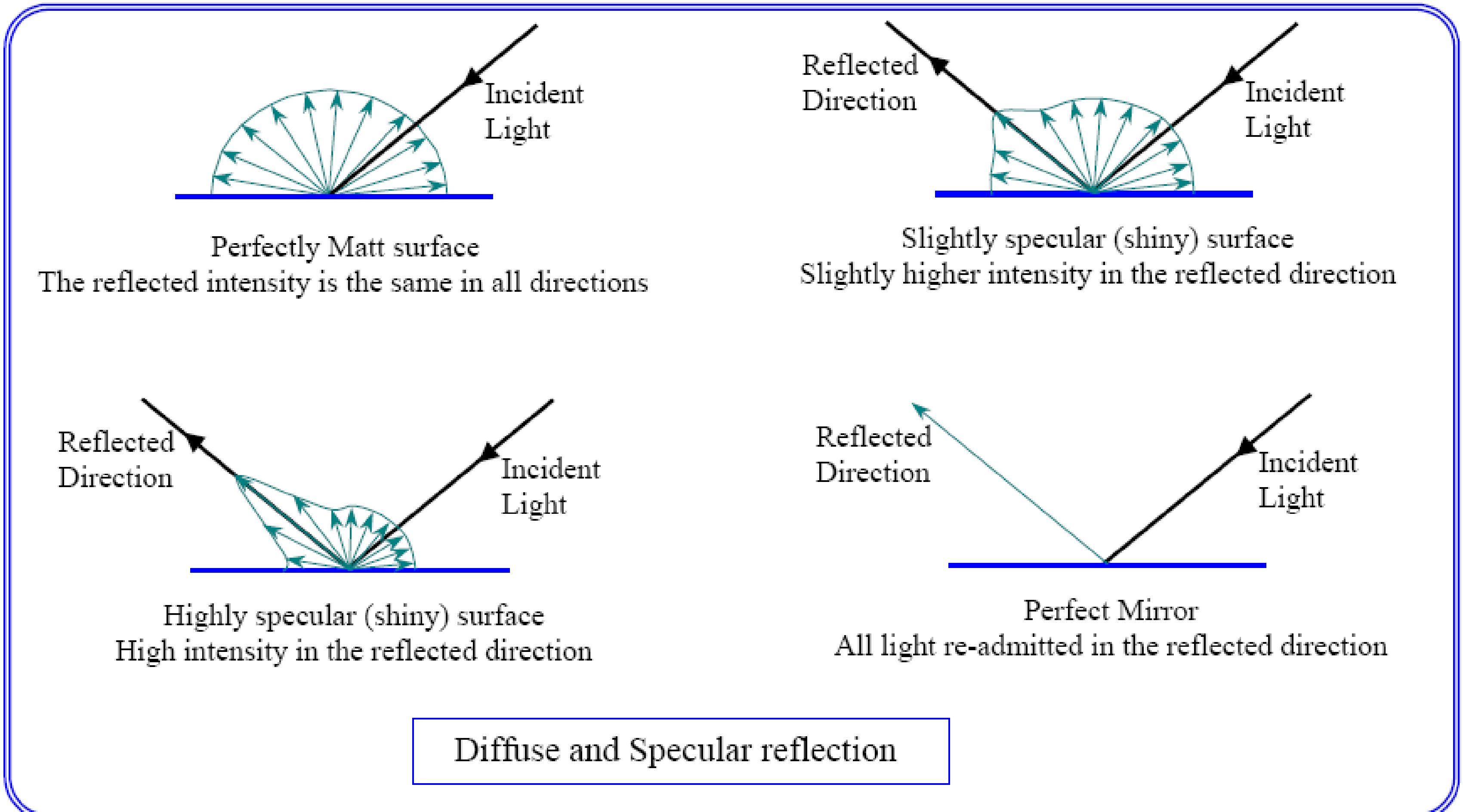
Using Colors



Shading planar polygons

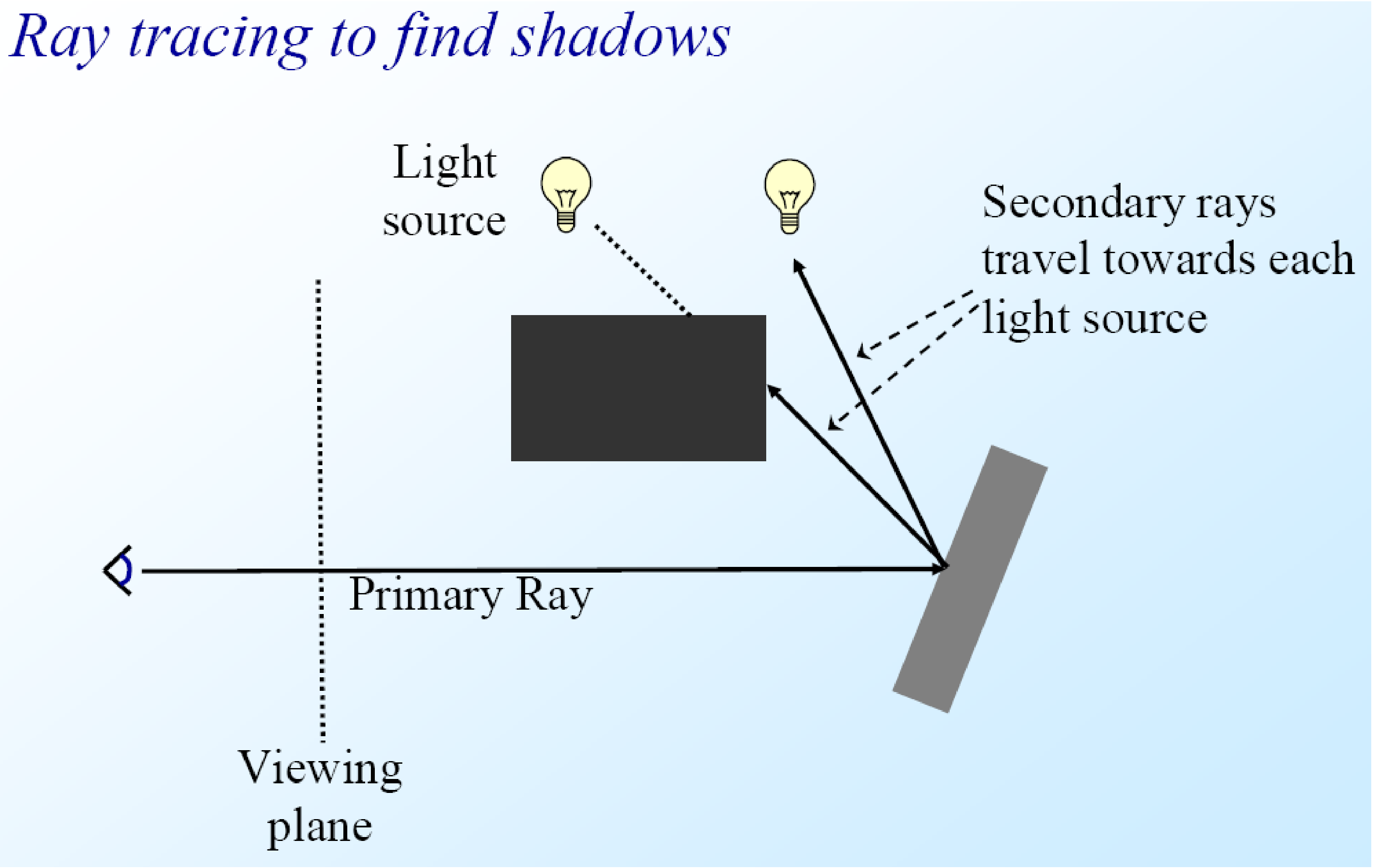


Shading planar polygons

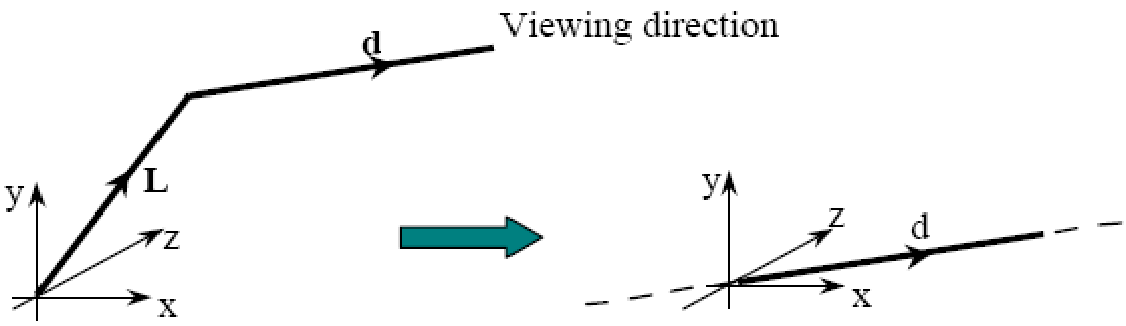


Diffuse and Specular reflection

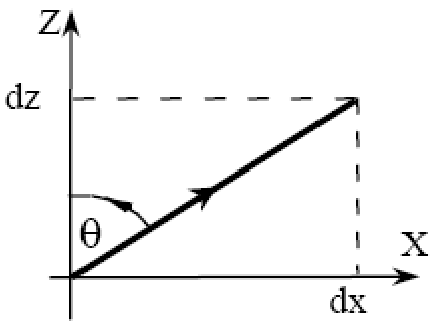
Ray Tracing


Ray tracing to find shadows
Light source
Secondary rays travel towards each light source
Primary Ray
Viewing plane

Scene Animation

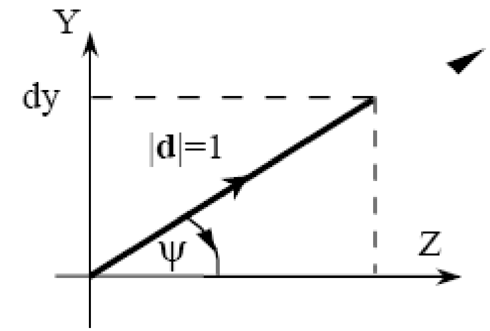


Step 1: Move origin to the required viewpoint



Step 2: Rotate about Y

$\cos\theta = dz/\sqrt{(dx*dx + dz*dz)}$
$\sin\theta = dx/\sqrt{(dx*dx + dz*dz)}$



Step 3: Rotate about X

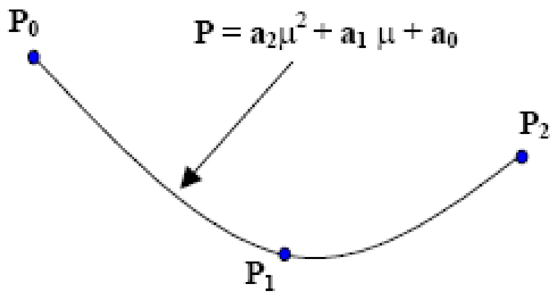
$\cos\psi = \sqrt{(dx*dx+dz*dz)}/|d|$
$\sin\psi = dy/|\mathbf{d}| = dy$

Transformation of the viewpoint

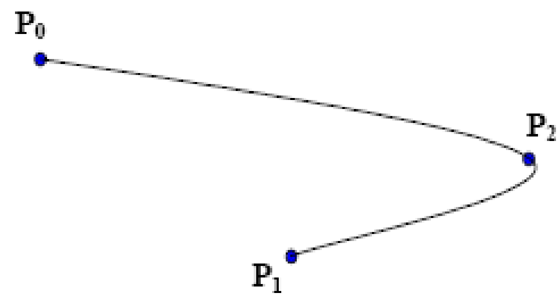
Radiosity Example

Radiosity Example

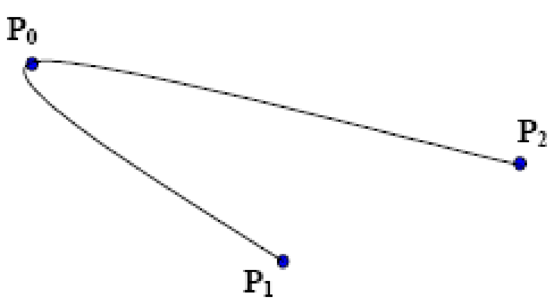
Splines



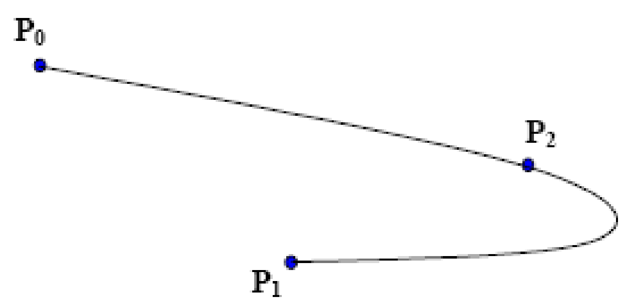
	P_0	P_1	P_2
μ	0	1/2	1



	P_0	P_1	P_2
μ	0	1	1/2

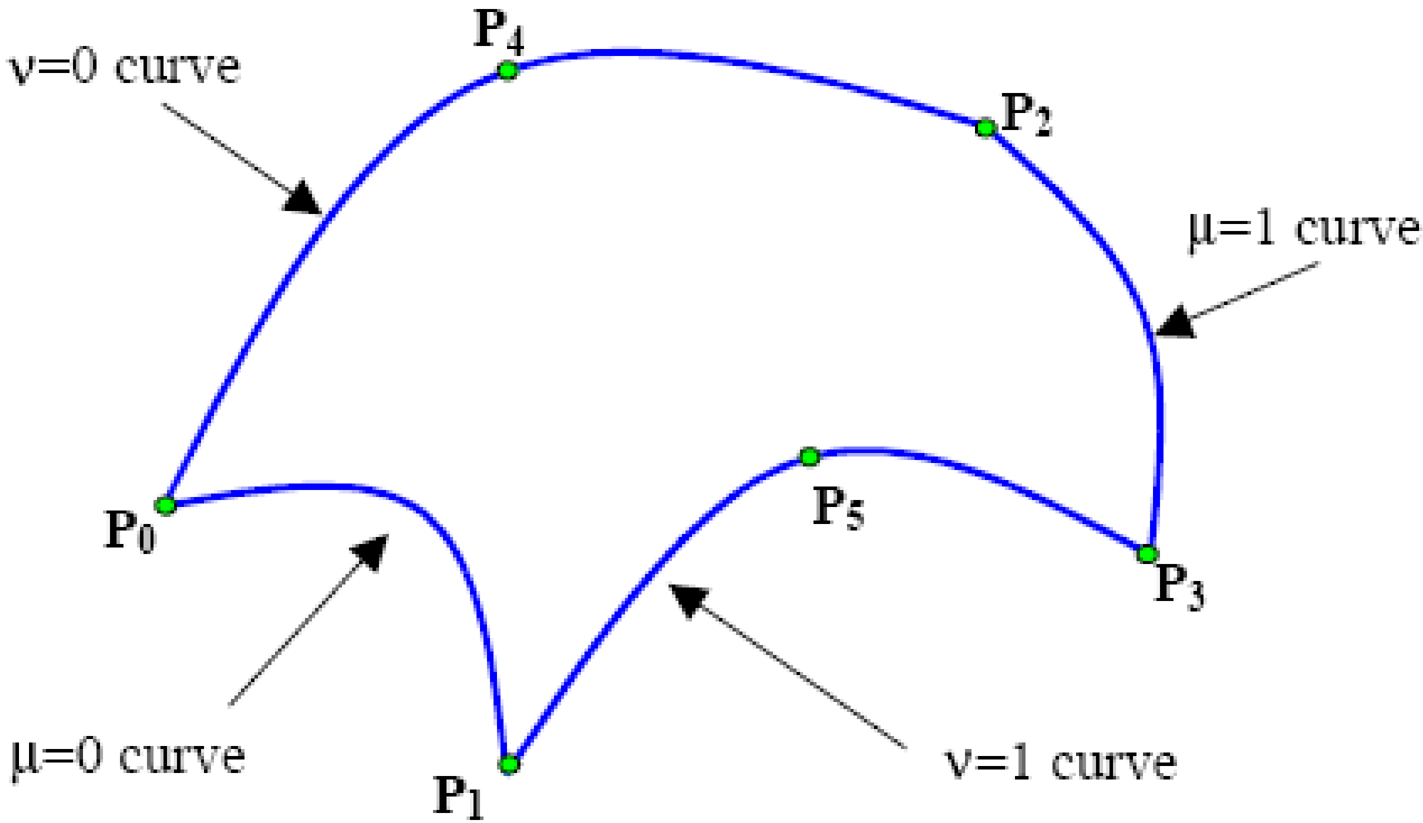


	P_0	P_1	P_2
μ	1/2	0	1

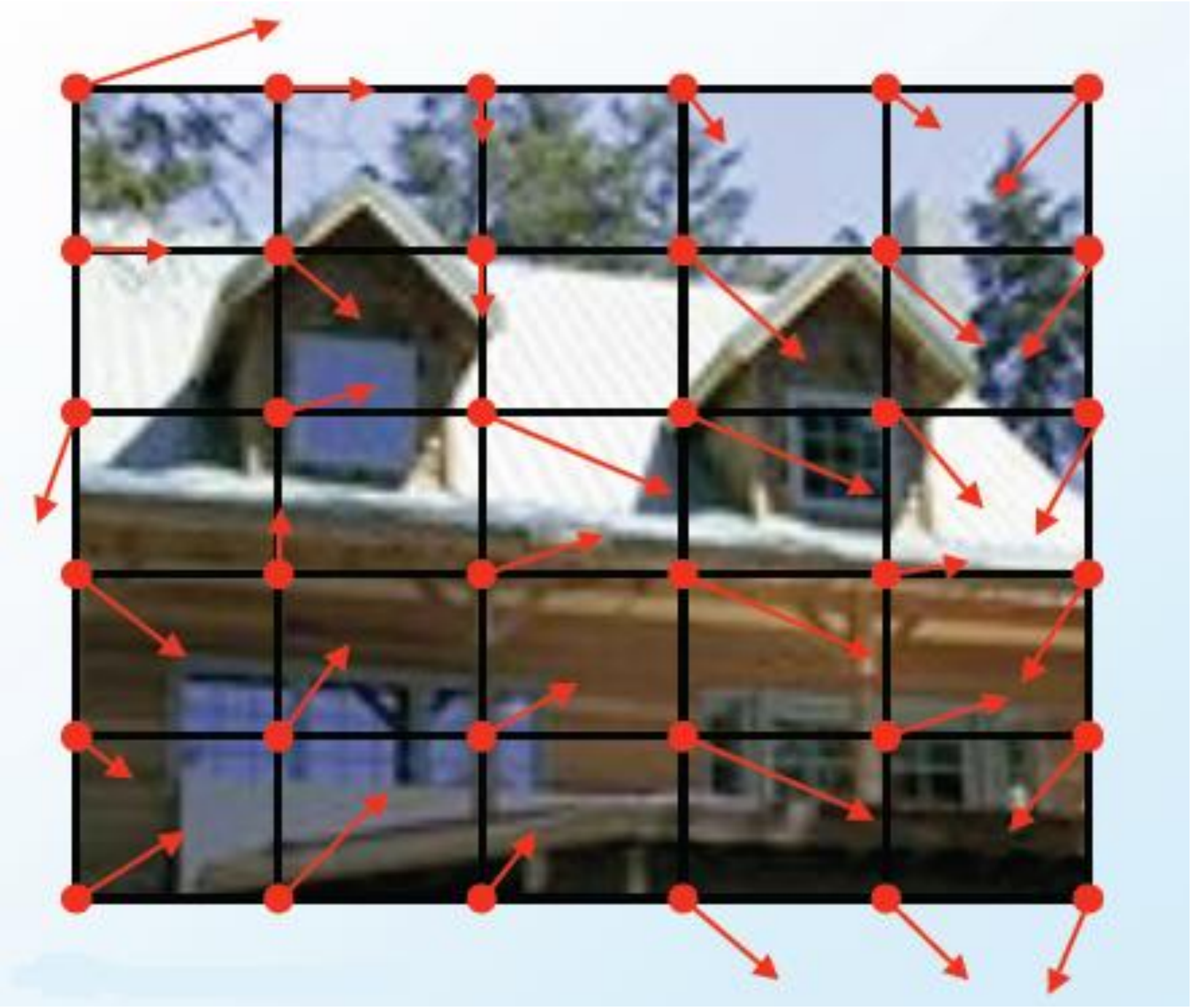


	P_0	P_1	P_2
μ	0	1	1/4

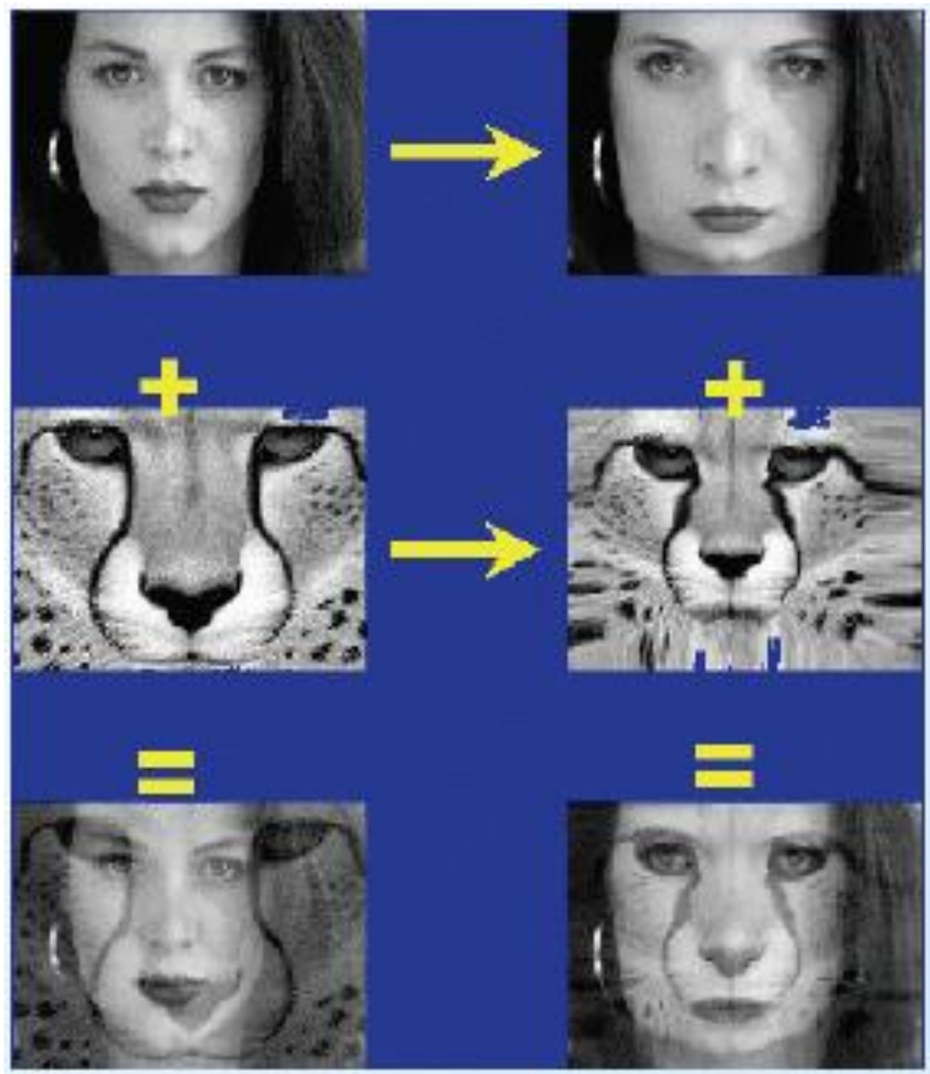
Surface Construction



Warping



Warping and Morphing



Part One

Device independent graphics: Raster and Vector Devices, Normalized Device Coordinates

Key elements of a graphics system

1. Processor
2. Memory
3. Framebuffer
4. Output devices:

    monitor (CRT LCD)

    printer
5. Input Devices:

    keyboard, mouse, joystick, spaceball

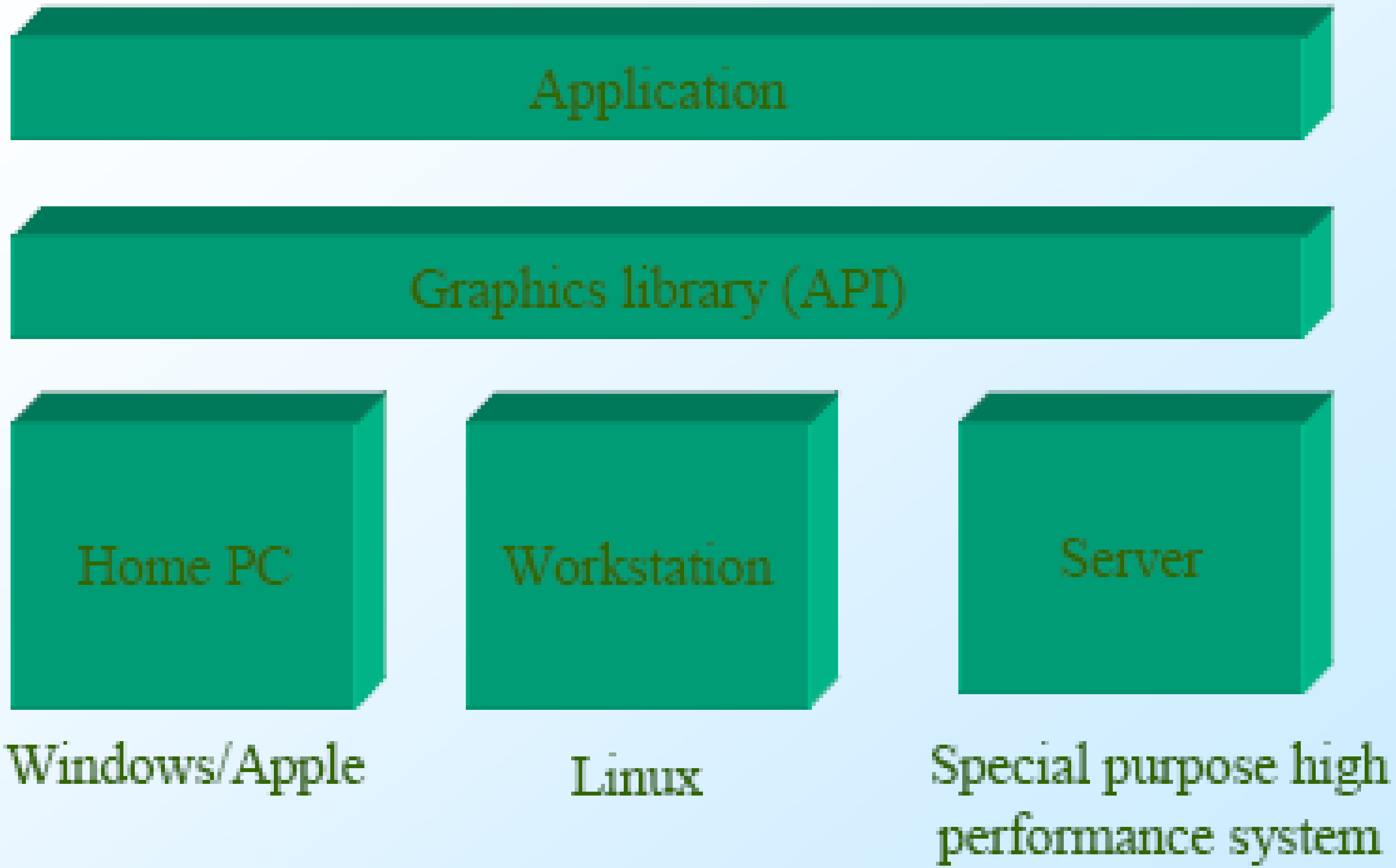
    data glove, eye tracker

Interactive Computer Graphics: APIs

Graphics output devices are many and diverse, but fortunately we don't need to worry too much about them since the operating system will generally take care of many of the details.

It provides us with an Application Programmer's Interface (API) which is a set of procedures for handling menus windows and, of course, graphics.

Interactive Computer Graphics: APIs



Interactive computer graphics: APIs

Problem: If speed is critical (i.e. computer games) it may be tempting to avoid using the API and access the graphics hardware directly.

➡ Device dependence

Existing APIs:

1. OpenGL
2. Direct3D
3. Java3D
4. VRML
5. Win32 API

Interactive Computer Graphics: OpenGL

OpenGL is hardware independent:

- PCs
- Workstations
- Supercomputers

OpenGL is operating system independent:

- Windows NT, Windows 2000, Windows XP
- Linux and Unix

OpenGL can perform rendering in

- software (i.e. processor)
- hardware (i.e. accelerated graphics card) if available

Interactive Computer Graphics: OpenGL

- OpenGL can be used from
  - C, C++
  - Ada, Fortran
  - Java
- OpenGL supports
  - polygon rendering
  - texture mapping and anti-aliasing
- OpenGL doesn't support
  - ray tracing
  - volume rendering

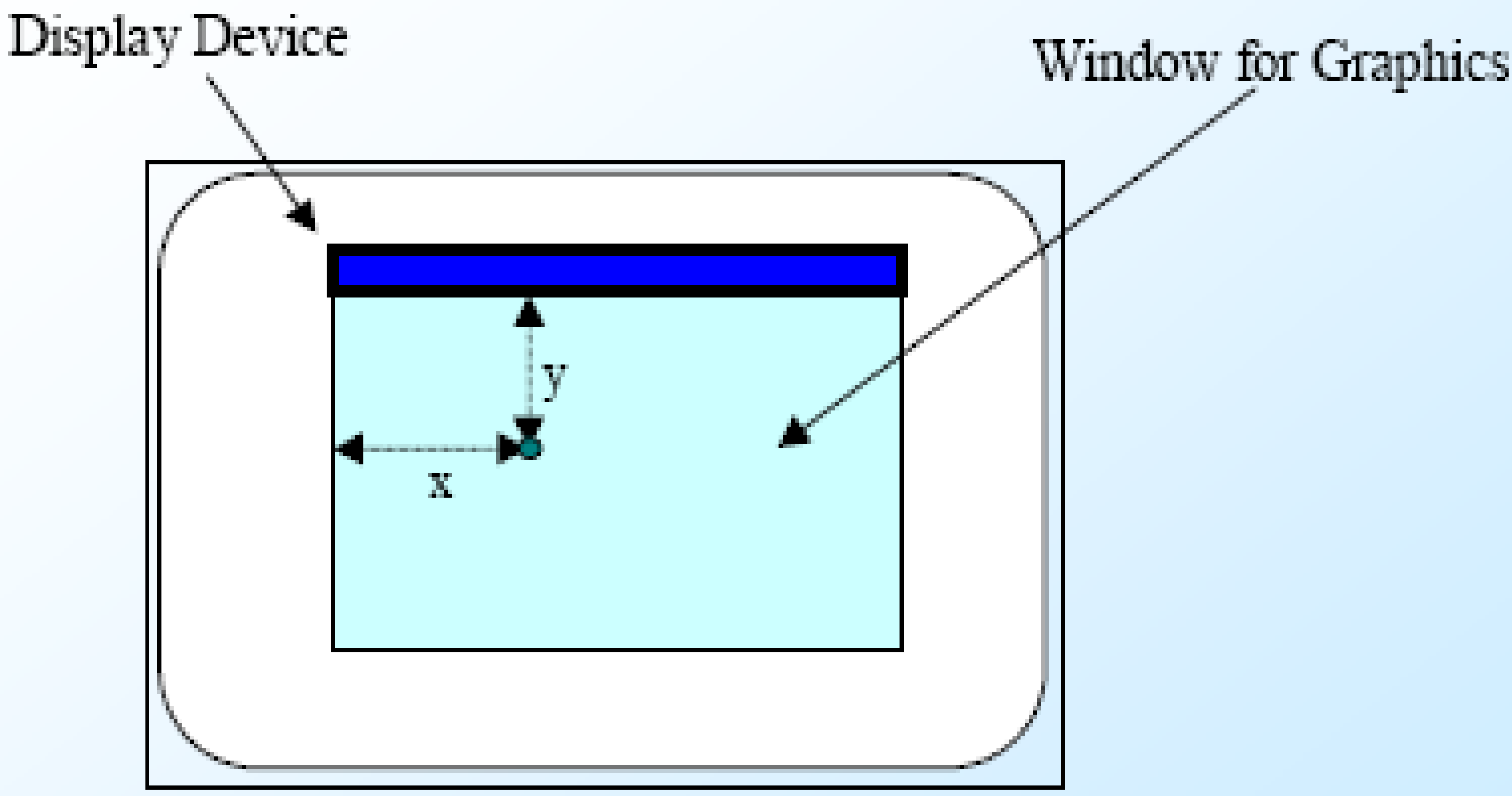
Raster Graphics

The most common graphics device is the raster display where the programmer plots points or pixels.

A typical (API) command might be:

```
SetPixel(x,y,colour)
```

Where x and y are pixel coordinates.



Normal meaning for *SetPixel(x,y,green)*

Bits per pixel

In some cases (laser printers) only one bit is used to represent each pixel allowing it to be on or off (black dot or white dot).

In old systems 8 bits are provided per pixel allowing 256 different shades to be represented.

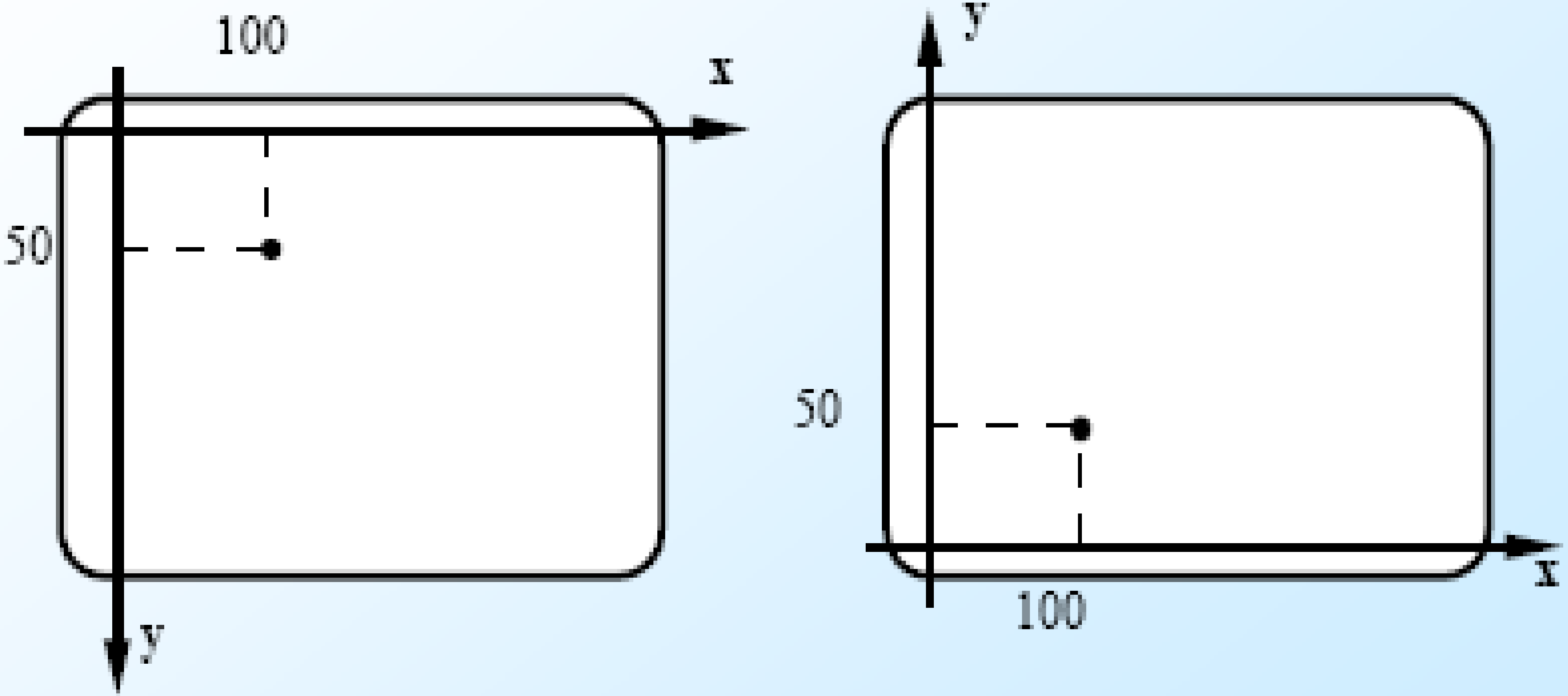
Most common today are pixels with 24 or 32 bit representation, allowing representation of millions of colours.

Pixel Addressing

Unfortunately not all systems adopt the same pixel addressing conventions.

Some have the origin at the top left corner, some have it at the bottom right hand corner.

Different pixel addressing conventions



Device Dependent Drawing Primitives

Each operating system provides us with the possibility of drawing graphics at the pixel level.

For example in the Windows 32 API we have:

```
MoveToEx(hdc xpix, ypix);
LineTo(hdc, xpix1, ypix1);
TextOut(hdc, xpix2, ypix2, message, length);
```

Where hdc is an identifier for the window, and xpix and ypix are pixel coordinates

Why aim for better device independence

1. In normal applications we want our pictures to adjust their size if the window is changed.

2. In graphics only applications we want our pictures to be independent of resolution

3. We want to be able to move graphics applications between different systems (PC, Workstation, Supercomputer etc.)

World Coordinate System

To achieve device independence we need to define a world coordinate system.

This will define our drawing area in units that are suited to the application:

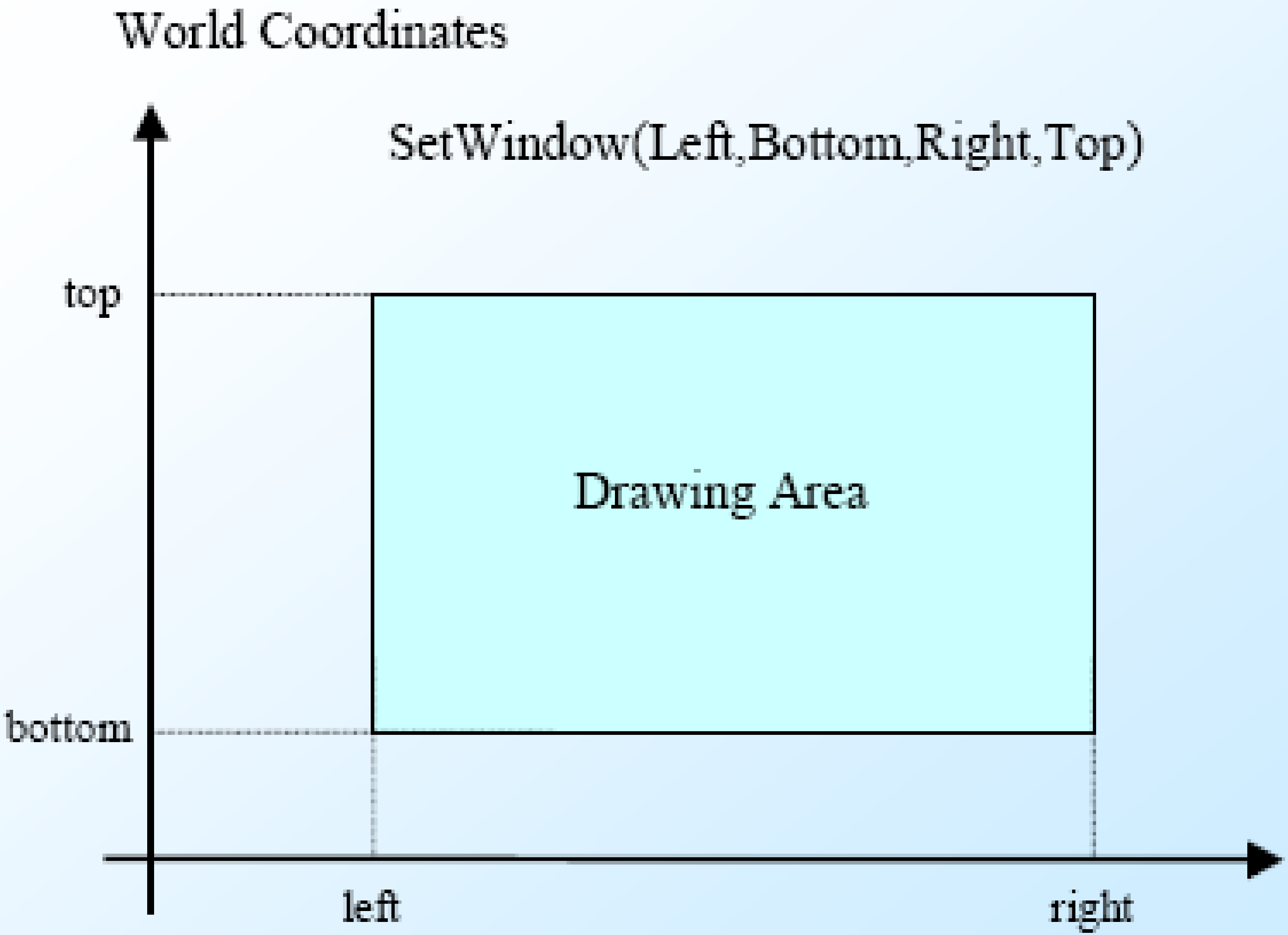
- meters
- light years
- microns
- etc

Worlds and Windows

It is common, but not universal to define the world coordinates with the command:

SetWindow(left,bottom,right,top)

We can think of this as a window onto the world matching a window on the screen


World Coordinates
SetWindow(Left,Bottom,Right,Top)
top
Drawing Area
bottom
left
right

Device independent Graphics Primitives

Having defined our world coordinate system we can implement drawing primitives to use with it. For example:

```
DrawLine(x1,y1,x2,y2);
DrawCircle(x1,y1,r);
DrawPolygon(PointArray);
DrawText(x1,y1,"A Message");
```

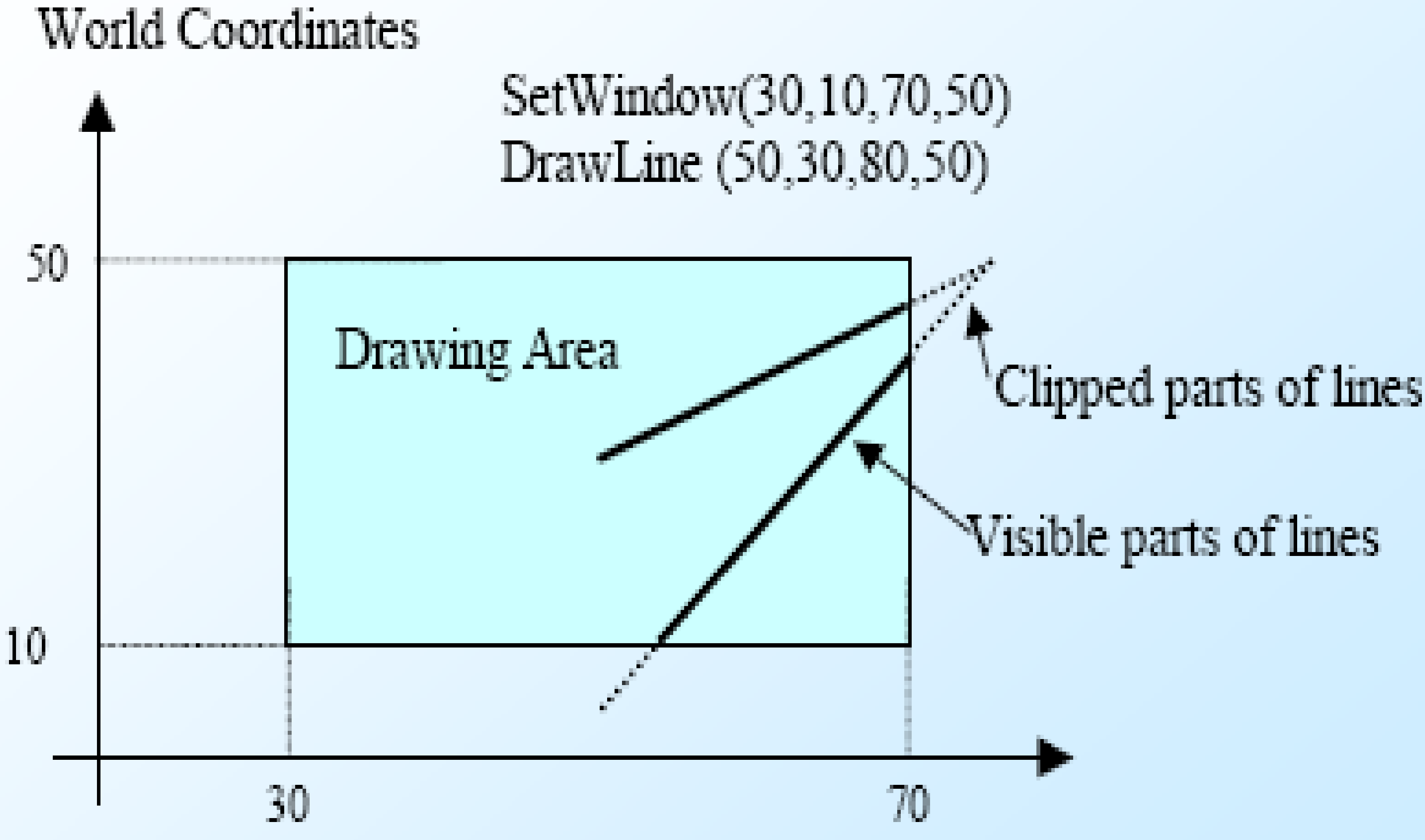
Normally any part of a graphics object outside the window is clipped.

Problem Break

What would you expect to be drawn in a graphics window by the following instructions:

```
SetWindow(30,10,70,50);
DrawLine(50,30,80,50);
DrawLine(80,50,50,5);
```

Solution


World Coordinates
SetWindow(30,10,70,50)
DrawLine (50,30,80,50)
50
Drawing Area
Clipped parts of lines
Visible parts of lines
10
30
70

Attributes

In device independent graphics primitives we usually avoid having a comprehensive set of parameters. For example, a line will have:

- Style (solid or dotted)
- Thickness (points)
- Colour

And text will have

- Font
- Size
- Colour

These are called attributes

Normalisation

We need to connect our device independent graphics primitives to the device dependent drawing commands so that we can see something on the screen.

This is done by the process of normalisation.

Normalisation

Having defined our world coordinates, and obtained our device coordinates we relate the two by simple ratios:

$$\frac{(Xw\text{-}WXmin)}{(WXMax\text{-}WXMin)} = \frac{(Xd - DXMin)}{(DXMax\text{-}DXMin)}$$

rearranging gives us

$$Xd = \frac{(Xw\text{-}WXmin) * (DXMax\text{-}DXMin)}{(WXMax\text{-}WXMin)} + DXmin$$

Normalisation

A similar equation allows us to calculate the Y pixel coordinate. The two can be combined into a simple pair of linear equations:

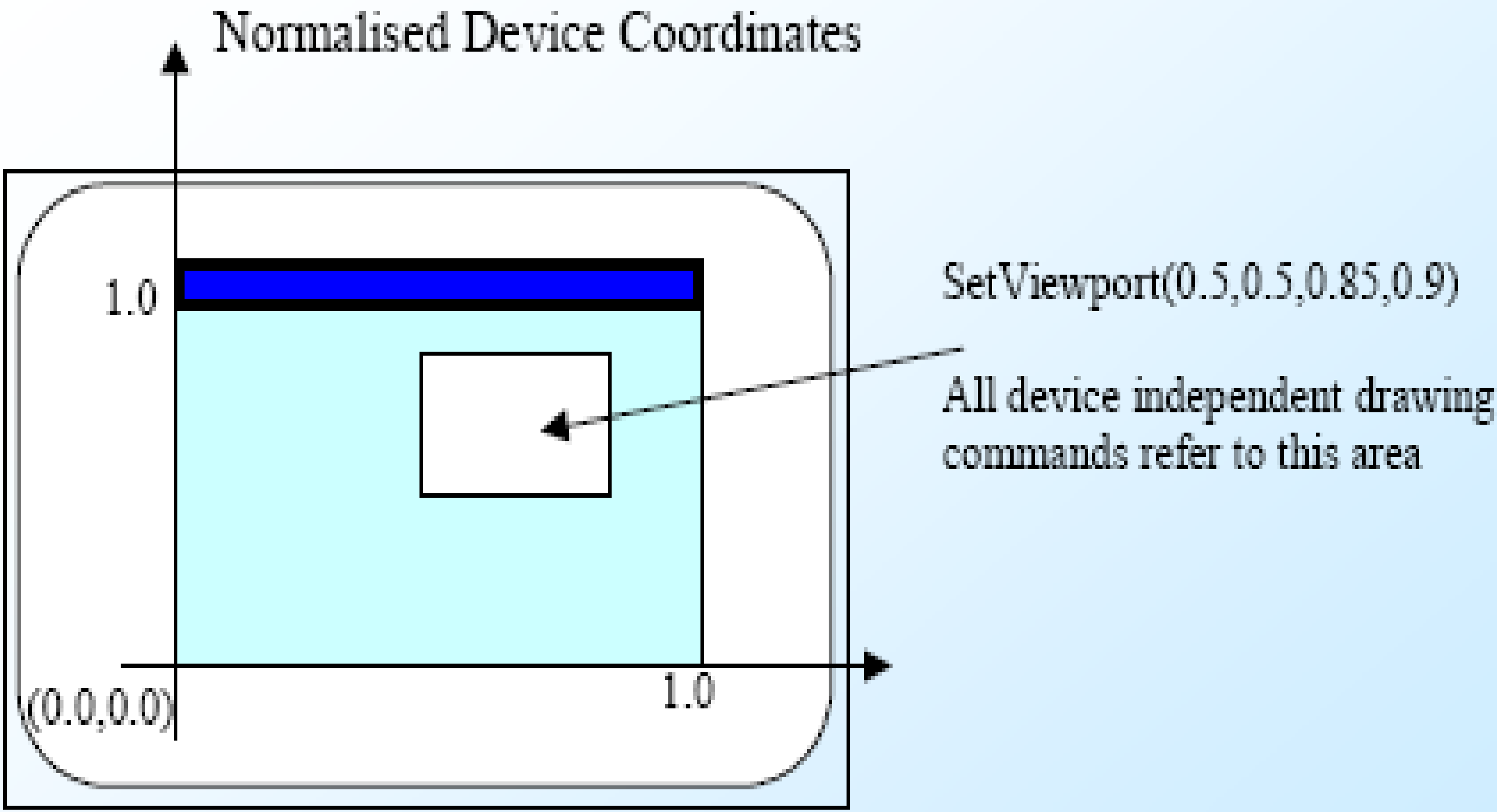
```
Xd := Xw * A + B;
Yd := Yw * C + D;
```

Viewports

Viewports are smaller parts of the window where the drawing is being displayed.

If we select a viewport, the normal convention is that all world coordinates are mapped to the viewport rather than the whole drawing area.

Viewports are defined in Normalised Device Coordinates where the whole drawing window has corners [0.0,0.0] and [1.0,1.0]


Normalised Device Coordinates
1.0
1.0
(0.0,0.0)
SetViewport(0.5,0.5,0.85,0.9)
All device independent drawing commands refer to this area

Mouse Position and Visible Markers

The mouse is simply a device which supplies the computer with three bytes of information (minimum) at a time, vis:

Distance Moved in X direction (ticks)

Distance Moved in Y direction (ticks)

Button Status

The provision of a visible marker on the screen is done by software.

Mouse Events

A mouse event occurs when something changes, ie it is moved or a button is pressed.

The mouse interrupts the operating system to tell it that an event has occurred and sends it the new data.

The operating system normally updates the position of the marker on the screen.

Callback procedure

The operating system informs the application program of mouse events (and other events) which are relevant to it.

The program must receive this information in what is called a callback procedure (or event loop).

Simple Callback procedure

```
while (executing) do
{     if (menu event) ProcessMenuRequest();
      if (mouse event)
      {       GetMouseCoordinates();
              GetMouseButtons();
              PerformMouseProcess();
      }
      if (window resize event) RedrawGraphics();
}
```

Assignment

Download and install GLUT from the following URL:
http://www.opengl.org/resources/libraries/glut/