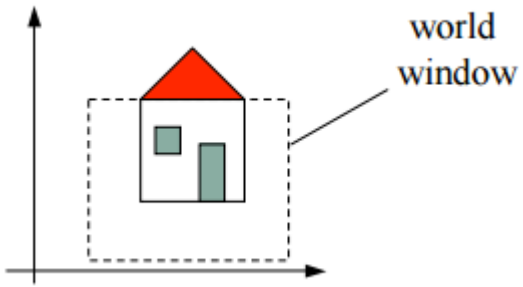
CS209 Компьютерийн график

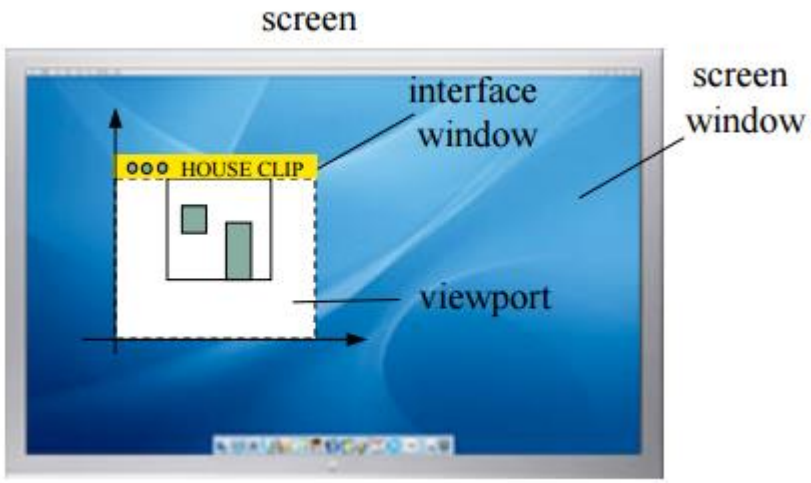
Лекц: Clipping

Course URL: http://elearn.sict.edu.mn

Нэр томъёо

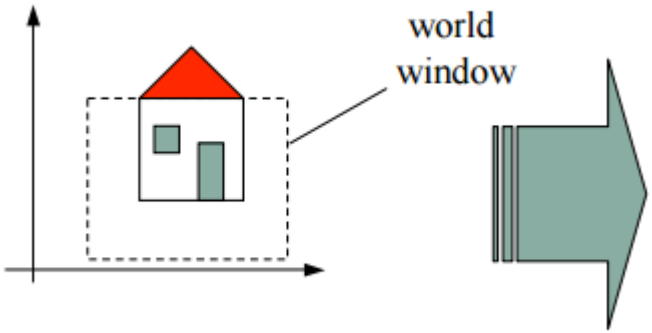
- **World Window** (Object Subspace) −Дэлгэцэнд харуулах world хэсгийг тодорхой лох тэгш өнцөгт
- **World Coordinate System** (Object Space) −application model тодорхойлсон ор он зай;
- **Interface Window, Image Coordinate System** (Image Subspace) – дэлгэцэнд х аруулах зургийн орон зай
- **Screen Coordinate System** (Image Space) −дэлгэцэнд харуулсан зургийн орон зай;

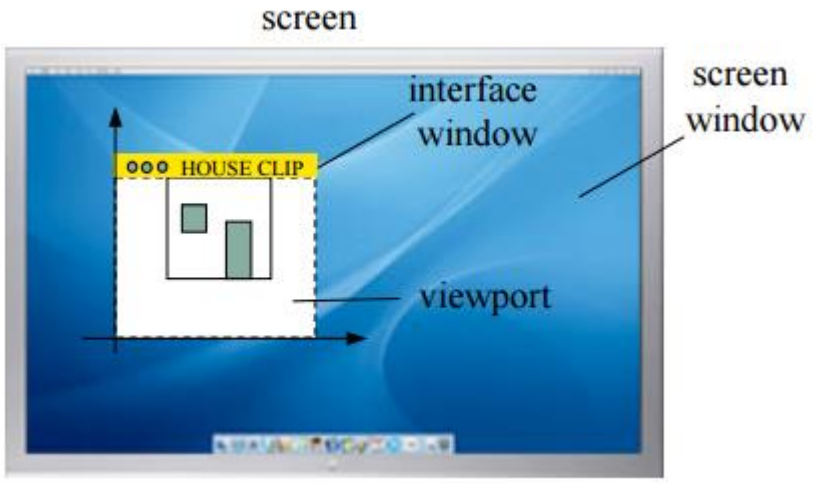




Нэр томъёо

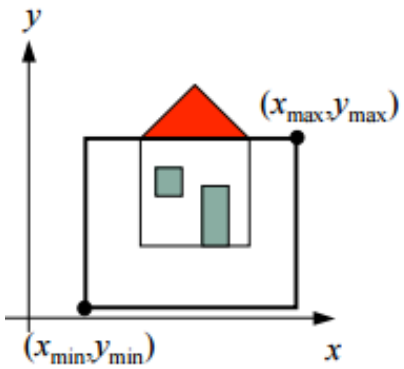
- **Viewport** (Image Subspace) цонхноос үзэгдэх зургийн орон зай дахь тэгш өнцөгт тайлбай
- **Viewing Transformations** –world координат дахь window-с зургийн координат (image coordinates) дахь viewport руу шилжих үйл явц



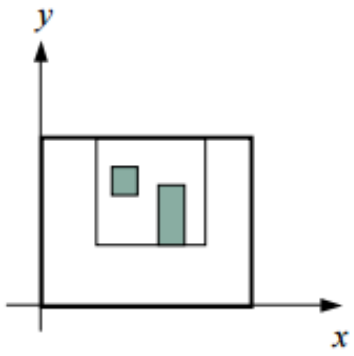


Window-Viewport Mapping

- window болон viewport өгөгдсөн бол window-г world координатаас дэлгэцийн координат (screen coordinates) дахь viewport руу хувиргах хувиргалтын матриц ямар байх вэ? Тус матрицыг дараах зургуудын дарааллаар гурван-алхамт хувиргалт хэлбэрээр өгч болно:

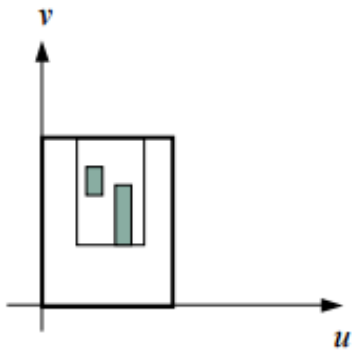


window
in world
coordinates



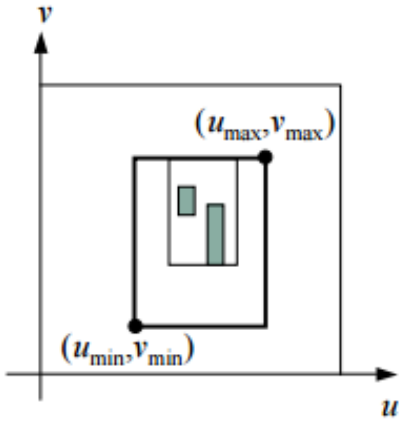
window
translated
to origin

$T(-x_{min}, -y_{min})$



window
scaled to size
of viewport

$$S\left(\frac{u_{max}-u_{min}}{x_{max}-x_{min}}, \frac{v_{max}-v_{min}}{y_{max}-y_{min}}\right)$$

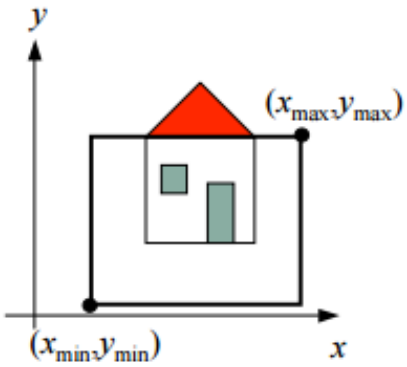


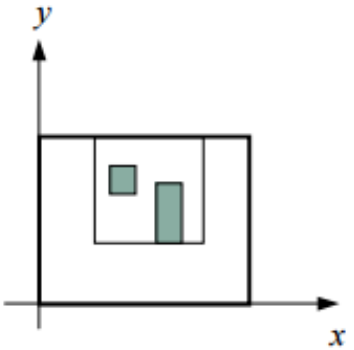
translated by
(u_{min}, v_{min})
to final position

$T(u_{min}, v_{min})$

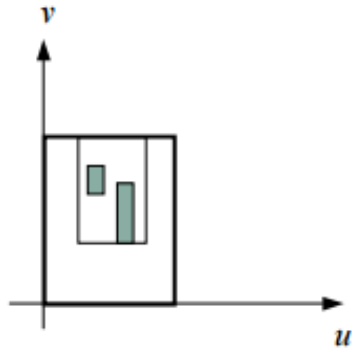
Window-Viewport Mapping

matrix representation

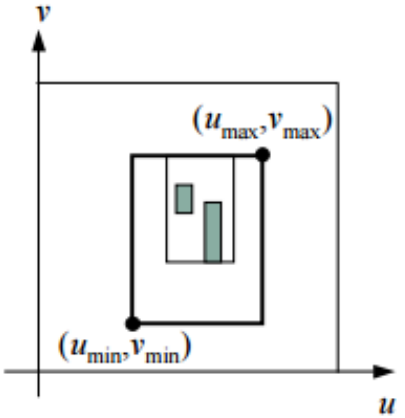




$T(-x_{min}, -y_{min})$



$S(\frac{u_{max}-u_{min}}{x_{max}-x_{min}}, \frac{v_{max}-v_{min}}{y_{max}-y_{min}})$



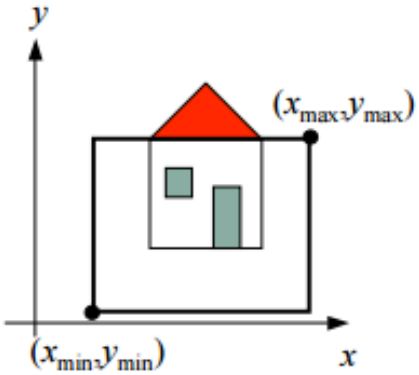
$T(u_{min}, v_{min})$

$$M_{wv} = T(u_{min}, v_{min}).S(\frac{u_{max}-u_{min}}{x_{max}-x_{min}}, \frac{v_{max}-v_{min}}{y_{max}-y_{min}}).T(-x_{min}, -y_{min})$$

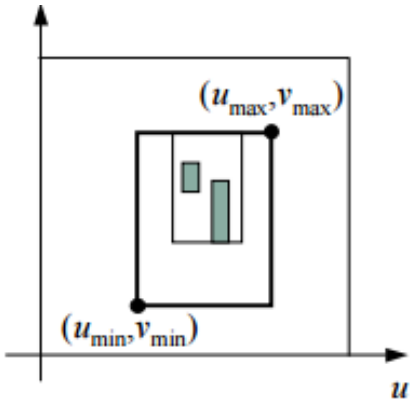
$$= \begin{bmatrix} 1 & 0 & u_{min} \\ 0 & 1 & v_{min} \\ 0 & 0 & 1 \end{bmatrix} . \begin{bmatrix} \frac{u_{max}-u_{min}}{x_{max}-x_{min}} & 0 & 0 \\ 0 & \frac{v_{max}-v_{min}}{y_{max}-y_{min}} & 0 \\ 0 & 0 & 1 \end{bmatrix} . \begin{bmatrix} 1 & 0 & -x_{min} \\ 0 & 1 & -y_{min} \\ 0 & 0 & 1 \end{bmatrix}$$

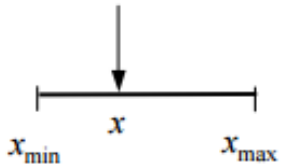
Window-Viewport Mapping

- Үүнийг хэрхэн хийх вэ?



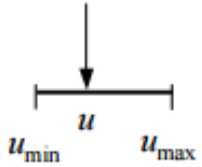
Keeping proportionality in mapping (x,y) to (u,v)

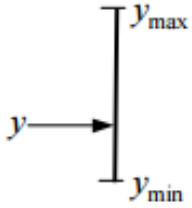




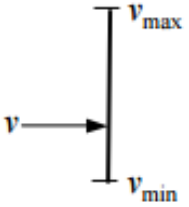
translation *scaling* *translation*

$$\frac{x - x_{min}}{x_{max} - x_{min}} = \frac{u - u_{min}}{u_{max} - u_{min}} \Leftrightarrow u = (x - x_{min}).\frac{u_{max} - u_{min}}{x_{max} - x_{min}} + u_{min}$$



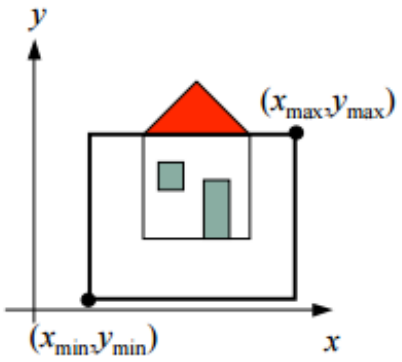


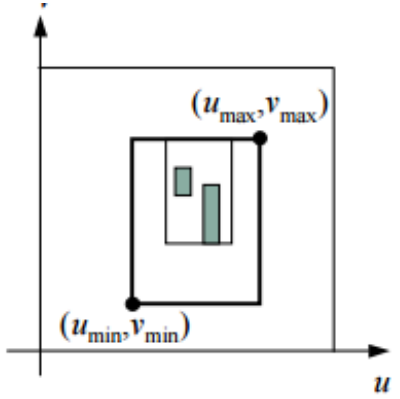
$$\frac{y - y_{min}}{y_{max} - y_{min}} = \frac{v - v_{min}}{v_{max} - v_{min}} \Leftrightarrow v = (y - y_{min}).\frac{v_{max} - v_{min}}{y_{max} - y_{min}} + v_{min}$$



Window-Viewport Mapping

- Жишээ





window(10.0,2.0,40.0,30.0)

viewport(100,50,250,300)

$$u = (x - 10.0).\frac{250 - 100}{40.0 - 10.0} + 100 \qquad \lambda_x = \frac{250 - 100}{40.0 - 10.0} = 5.0$$

$$v = (y - 5.0).\frac{300 - 50}{30.0 - 5.0} + 50 \qquad \lambda_y = \frac{300 - 50}{30.0 - 5.0} = 10.0$$

Window-Viewport Mapping

in OpenGL

- **`gluOrtho2D(left, right, bottom, top)`**
  - Sets up a 2-D orthographic viewing region or *world window*. Defined by two vertical clipping planes `left` and `right` and two horizontal clipping planes `bottom` and `top`.
  - The *world window* by default is (-1,1,-1,1).
  - Defines a 2-D orthographic projection matrix.
  - Sets up the window-viewport mapping, being the viewport defined by the following function:
- **`glViewport(x, y, width, height)`**
  - Sets up the viewport in the *interface window*, where `x,y` specify the lower left corner, and `width`, `height` its dimensions.
  - By default, it uses the whole graphics area of the interface window.
  - There may be various viewports inside the interface window.

OpenGL 2D Viewing

OpenGL дахь 2D Viewing тодорхойлолт:

- Стандарт загвар, нэр томъёог дагаж мөрддөг

Эхлээд проекц тодорхойлно

Projection Matrix (ModelView matrix оронд):

```
glMatrixMode(GL_PROJECTION);
```

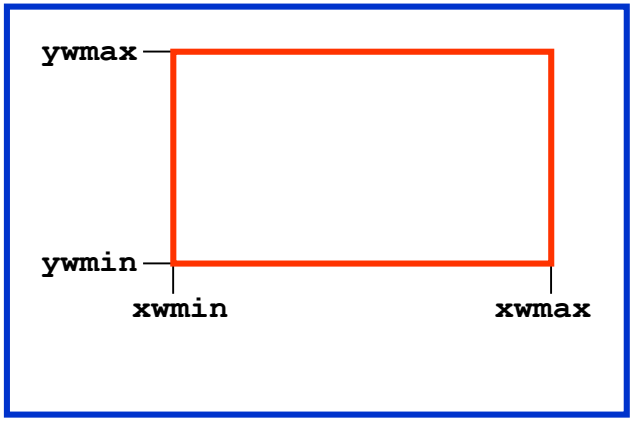
OpenGL 2D Viewing 2

Дараа нь 2D clipping window тодорхойлно:

```
gluOrtho2D(xwmin, xwmax, ywmin, ywmax);
```

xwmin, xwmax: хэвтээ тэнхлэгийн муж, world coordinates

ywmin, ywmax: босоо тэнхлэгийн муж, world coordinates



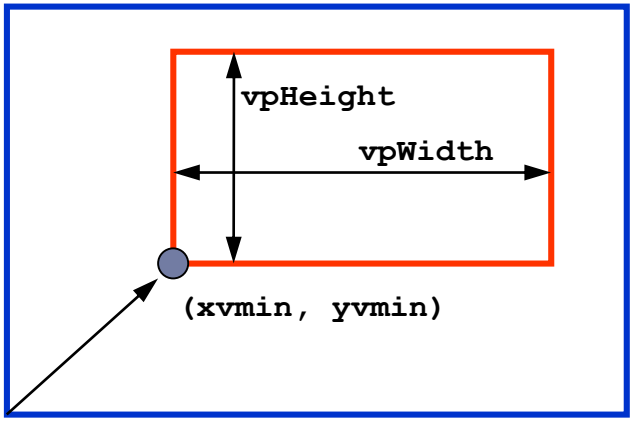
OpenGL 2D Viewing 3

Эцэст viewport тодорхойлно:

```
glViewport(xvmin, yvmin, vpWidth, vpHeight);
```

xvmin, yvmin: зүүн доод булангийн координат (in pixel coordinates);

vpWidth, vpHeight: өргөн ба өндөр (in pixel coordinates);



OpenGL 2D Viewing 4

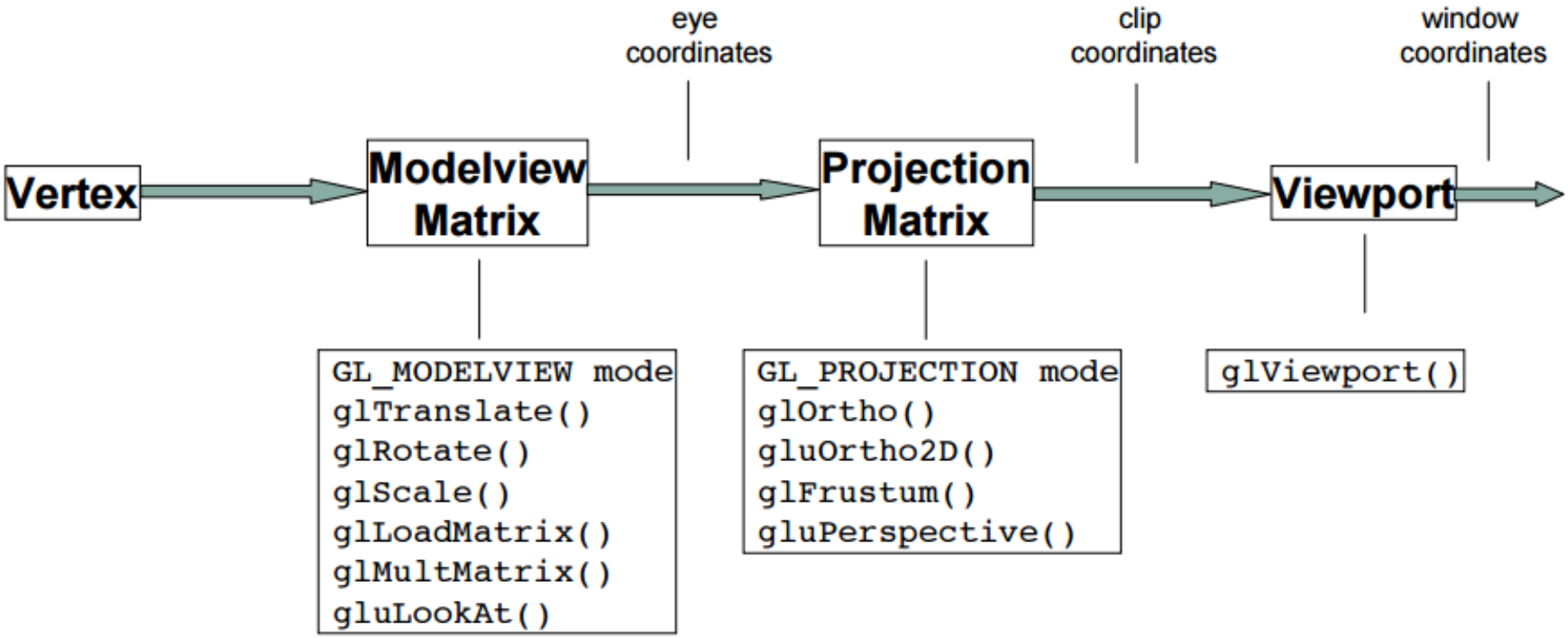
Товчхондоо:

```
glMatrixMode(GL_PROJECTION);
gluOrtho2D(xwmin, xwmax, ywmin, ywmax);
glViewport(xvmin, yvmin, vpWidth, vpHeight);
```

Гажуудал үүсгэхгүйн тулд үүнийг шалгаж үзэх хэрэгтэй:

```
(ywmax - ywmin)/(xwmax - xwmin) = vpWidth/vpHeight
```

Pipeline of OpenGL Transformations



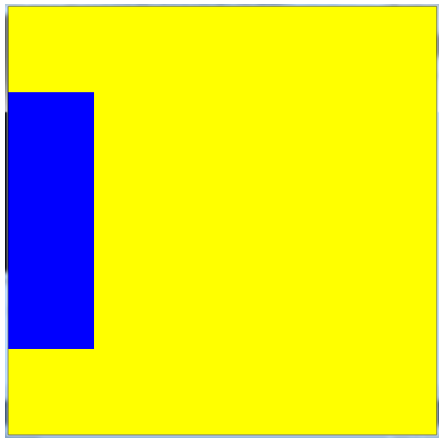
OpenGL-ийн жишээ

default viewport

```
/* * WV-defaultViewport.cc - Using the default viewport * Abel Gomes  */
#include <OpenGL/gl.h>          // Header File For The OpenGL Library
#include <OpenGL/glu.h>         // Header File For The GLu Library
#include <GLUT/glut.h>          // Header File For The GLut Library
#include <stdlib.h>

void draw(){
          // Make background colour yellow
     glClearColor( 100, 100, 0, 0 );
     glClear ( GL_COLOR_BUFFER_BIT );

          // Sets up the PROJECTION matrix
     glMatrixMode(GL_PROJECTION);
     glLoadIdentity();
     gluOrtho2D(0.0,50.0,-10.0,40.0);  // also sets up world window

     // Draw BLUE rectangle
     glColor3f( 0, 0, 1 );
     glRectf(0.0,0.0,10.0,30.0);

          // display rectangles
     glutSwapBuffers();
}                                                    // end of draw()
```

default viewport (cont.)

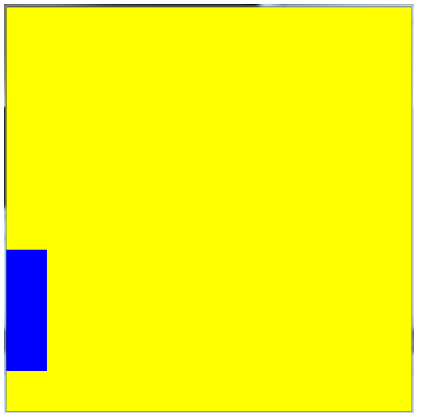
```
// Keyboard method to allow ESC key to quit
void keyboard(unsigned char key,int x,int y)
{
     if(key==27) exit(0);
}

int main(int argc,  char ** argv)
{
     glutInit(&argc, argv);
          // Double Buffered RGB display
     glutInitDisplayMode( GLUT_RGB | GLUT_DOUBLE);
          // Set window size
     glutInitWindowSize( 500,500 );
     glutCreateWindow("Default viewport spans the whole interface window");
          // Declare the display and keyboard functions
     glutDisplayFunc(draw);
     glutKeyboardFunc(keyboard);
          // Start the Main Loop
     glutMainLoop();
     return 0;
}
```



OpenGL-ийн жишээ

single viewport

```
/* * WV-singleViewport.cc - Using a single viewport * Abel Gomes  */
#include <OpenGL/gl.h>        // Header File For The OpenGL Library
#include <OpenGL/glu.h>       // Header File For The GLu Library
#include <GLUT/glut.h>        // Header File For The GLut Library
#include <stdlib.h>
void draw(){
          // Make background colour yellow
     glClearColor( 100, 100, 0, 0 );
     glClear ( GL_COLOR_BUFFER_BIT );

          // Sets up viewport spanning the left-bottom quarter of the interface window
     glViewport(0,0,250,250);
          // Sets up the PROJECTION matrix
     glMatrixMode(GL_PROJECTION);
     glLoadIdentity();
     gluOrtho2D(0.0,50.0,-10.0,40.0);  // also sets up world window

     // Draw BLUE rectangle
     glColor3f( 0, 0, 1 );
     glRectf(0.0,0.0,10.0,30.0);

          // display rectangles
     glutSwapBuffers();
}                                                    // end of draw()
```



OpenGL-ийн жишээ

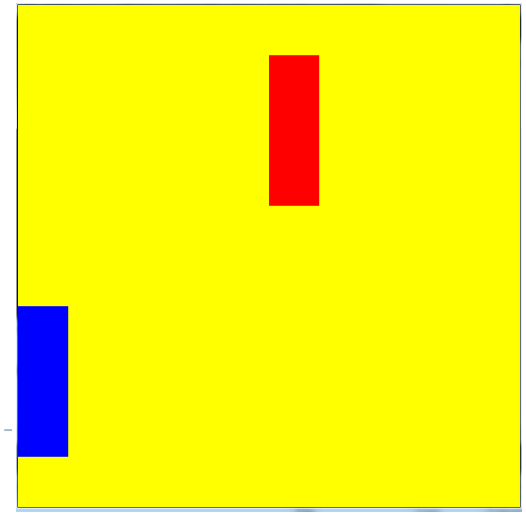
two viewports

```
/* * WV-twoViewports.cc - Using two viewports * Abel Gomes  */
#include <OpenGL/gl.h>        // Header File For The OpenGL Library
#include <OpenGL/glu.h>       // Header File For The GLu Library
#include <GLUT/glut.h>        // Header File For The GLut Library
#include <stdlib.h>

void draw(){
          // Make background colour yellow
     glClearColor( 100, 100, 0, 0 );
     glClear ( GL_COLOR_BUFFER_BIT );

          // Sets up FIRST viewport spanning the left-bottom quarter of the interface window
     glViewport(0,0,250,250);
          // Sets up the PROJECTION matrix
     glMatrixMode(GL_PROJECTION);
     glLoadIdentity();
     gluOrtho2D(0.0,50.0,-10.0,40.0);  // also sets up world window

     // Draw BLUE rectangle
     glColor3f( 0, 0, 1 );
     glRectf(0.0,0.0,10.0,30.0);
```

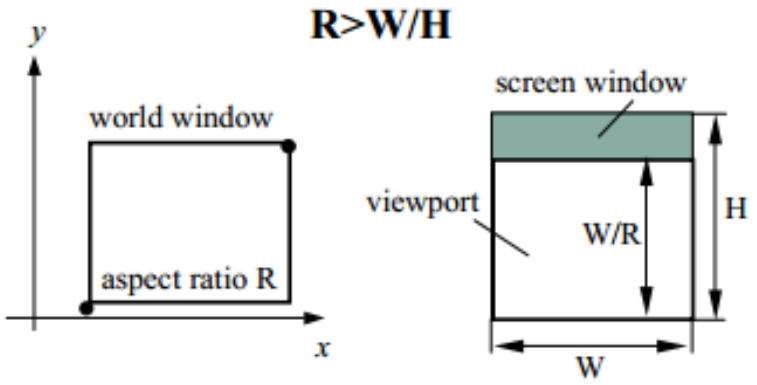
OpenGL-ийн жишээ

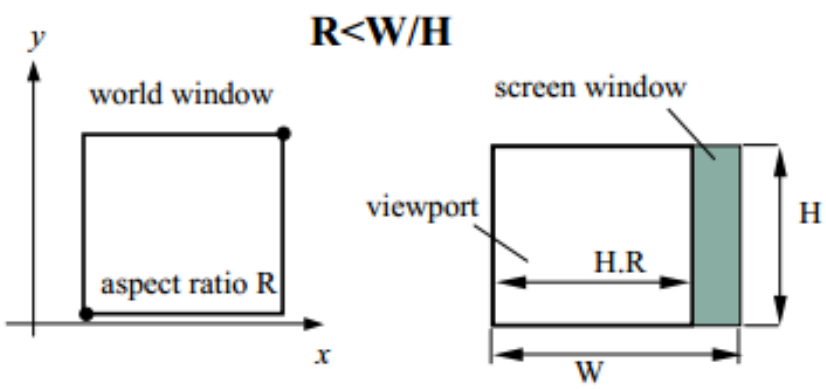
two viewports (cont.)

```
/*  rest of the function draw() */


        // Sets up SECOND viewport spanning the right-top quarter of the interface window
    glViewport(250,250,250,250);
        // Sets up the PROJECTION matrix
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0.0,50.0,-10.0,40.0);  // also sets up world window

    // Draw RED rectangle
    glColor3f( 1, 0, 0 );
    glRectf(0.0,0.0,10.0,30.0);

        // display rectangles
    glutSwapBuffers();
}                                                    // end of draw()
```



Viewport автоматаар тохируулах



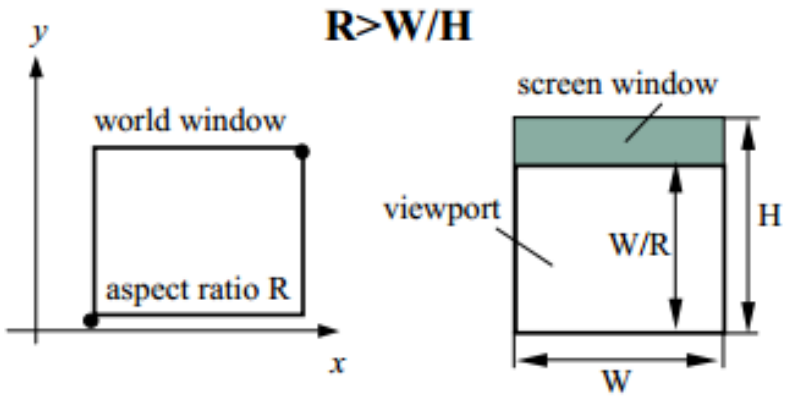



```
glViewport(0,0,W,W/R);
```

```
glViewport(0,0,H*R,H);
```

Example: short window

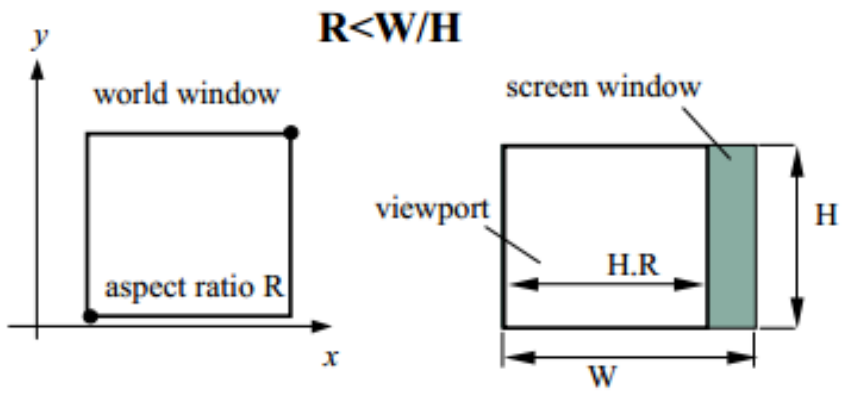
- If the world window has R=2.0 and the screen has H=200 and W=360, then W/H=1.8.
- Therefore, we fall in first case, and the viewport is set to 180 pixels high and 360 pixels wide.




```
glViewport(0,0,W,W/R);

glViewport(0,0,360,360/2);
```

Example: tall window

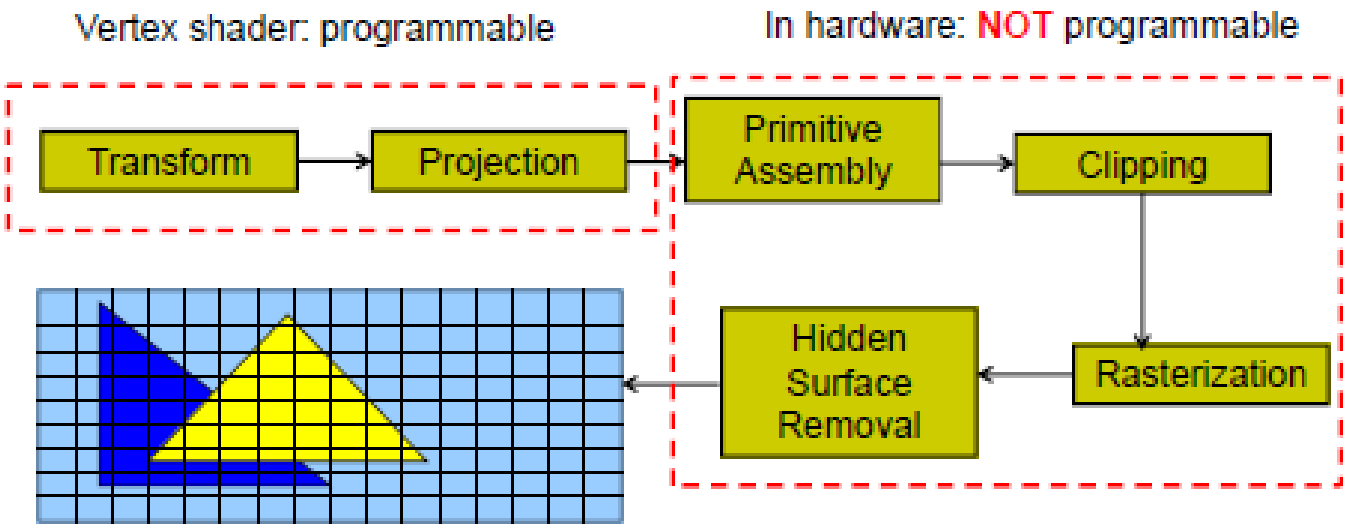
- If the world window has R=1.6 and the screen has H=200 and W=360, then W/H=1.8.
- Therefore, we fall in second case, and the viewport is set to 200 pixels high and 320 pixels wide.




```
glViewport(0,0,H*R,H);

glViewport(0,0,320,200);
```

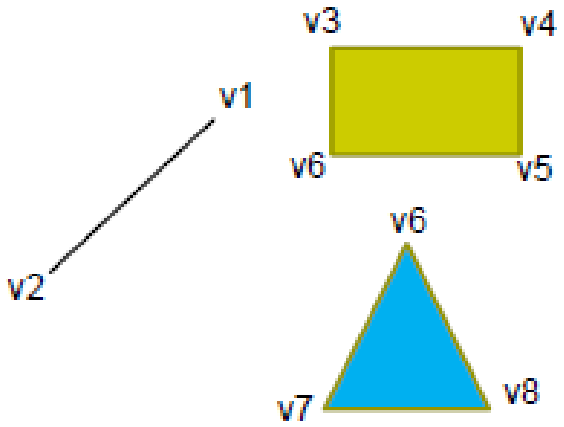
OpenGL үе шат

- Projection хийгдсэний дараа объектийг дэлгэцэнд зур ахын өмнө хэд хэдэн үе шатуудыг дамжина.
- Эдгээр үе шатууд нь програмчлагдахгүй.



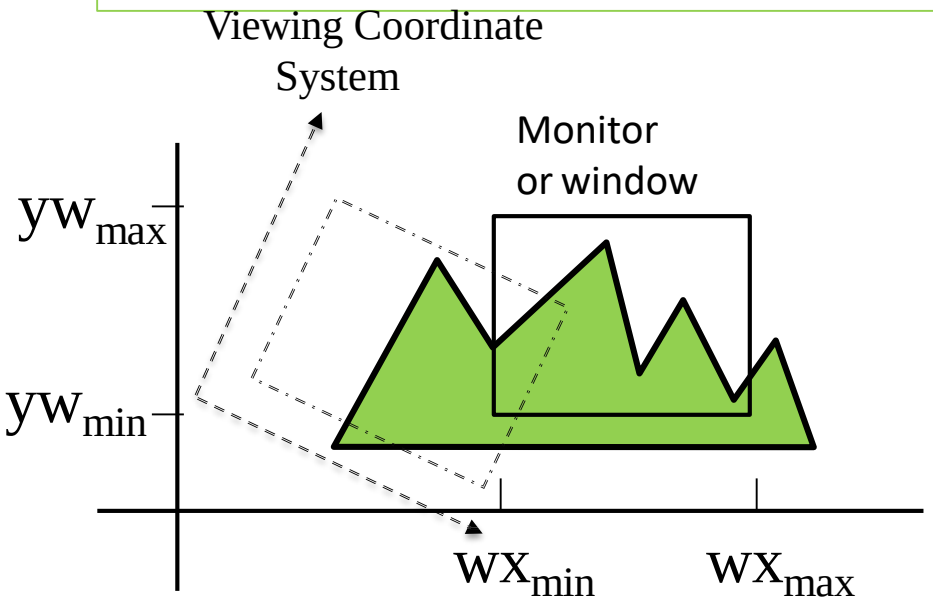
ТХ –ийн үе шат: Примитив угсрах

- Энэ үе хүртэл: Салангид vertex-д transformations, projections –г хэрэгжүүлнэ.
- Примитив угсрах: transformations, projections –г хэрэгжүүлсэний дараагаар салангид vertex-д примитив рүү групплэгдэнэ.
- Жнь: v6, v7 болон v8 гурвалжин руу групплэгдсэн

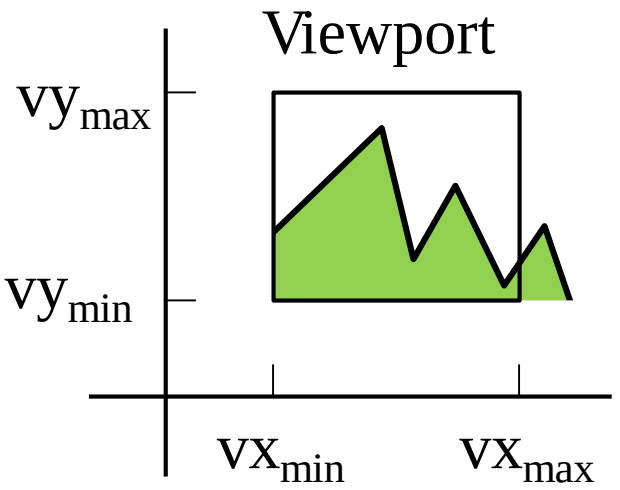


Viewing transformation

- Мастер координатын систем, нийтлэг нэр нь world coordinate system
  - ✓ Clipping window: Юуг харуулахыг хүсч байна вэ?
  - ✓ Viewport: Бид үүнийг хаанаас харуулахыг хүсч байна вэ?



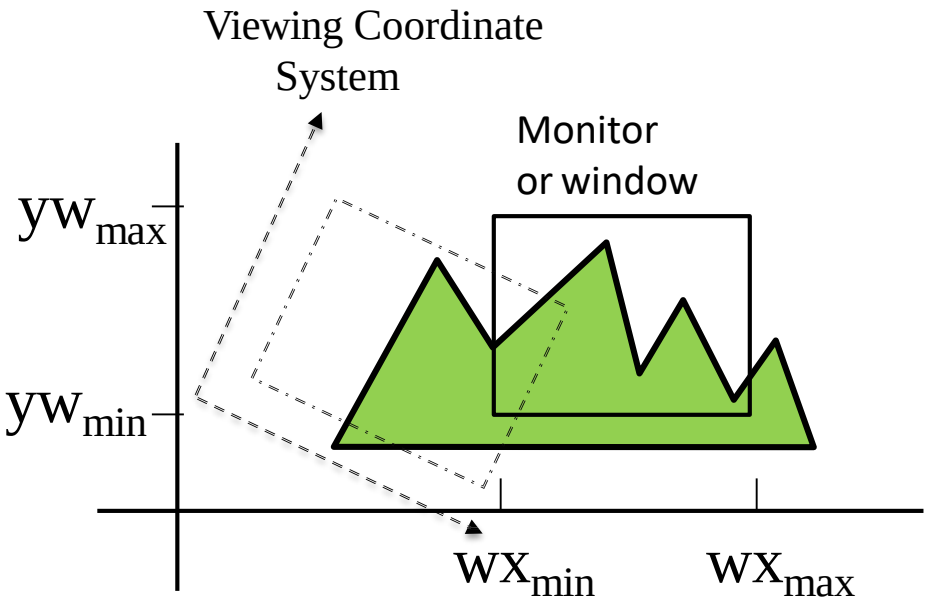
a) World Coordinate System



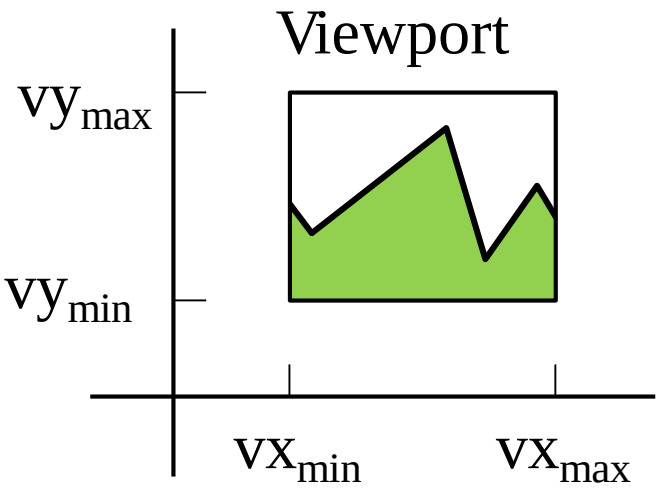
b) Device Coordinate System

Viewing transformation

- **Viewing Transformation**: world болон viewing координатын системүүдийн хооронд координатыг буулгах (mapping) үйлдэл юм.
  - ✓ clipping window -ийг viewport руу буулгана



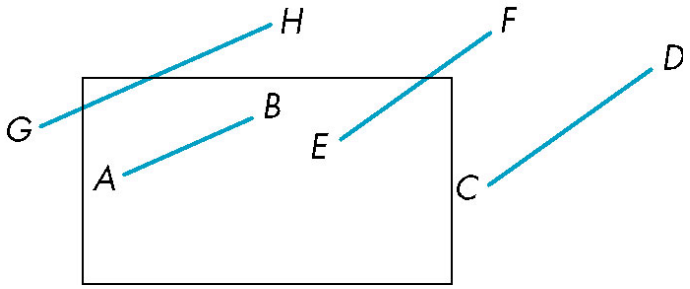
a) World Coordinate System



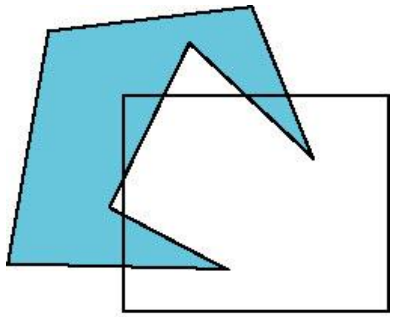
b) Device Coordinate System

ТХ –ийн үе шат: **Clipping**

- Примитивүүдийг угсарсны дараа примитив бүрийн хувьд хийгдэх үйлдэл
- **Clipping:** frustum-аас гадна орших примитивийг устгах **(lines, polygons, text**)
- lines, polygons-ний хувьд clipping хийхэд хялбар.
- text-ний хувьд clipping хийхэд хялбар биш.



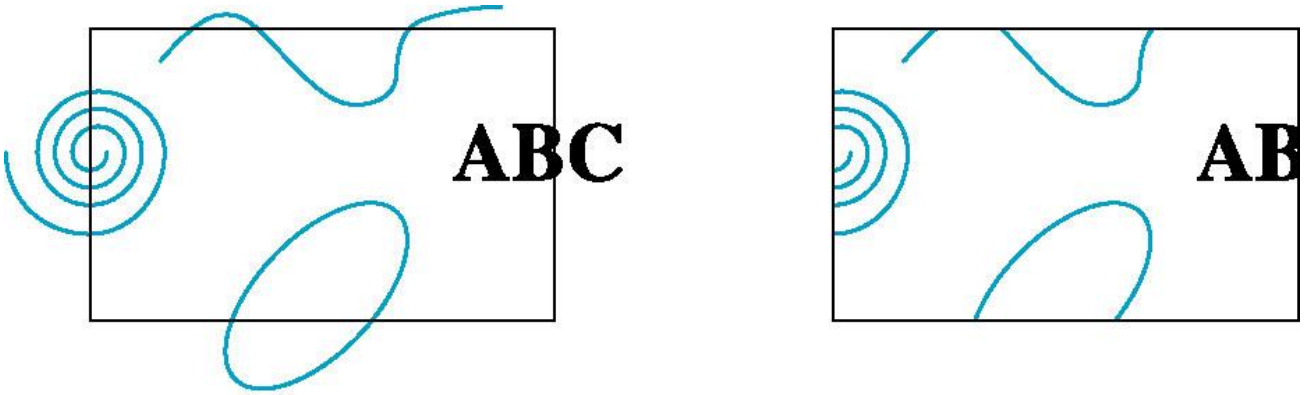
Clipping lines



Clipping polygons

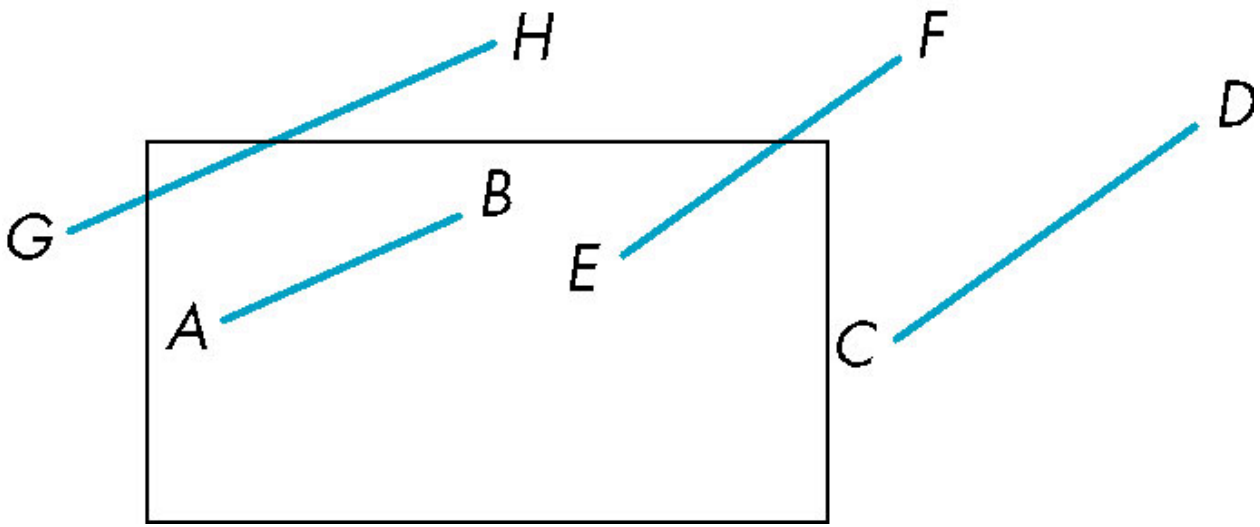
Хоёр хэмжээст (2D) clipping

- Lines
- Polygons
- Curves
- Text

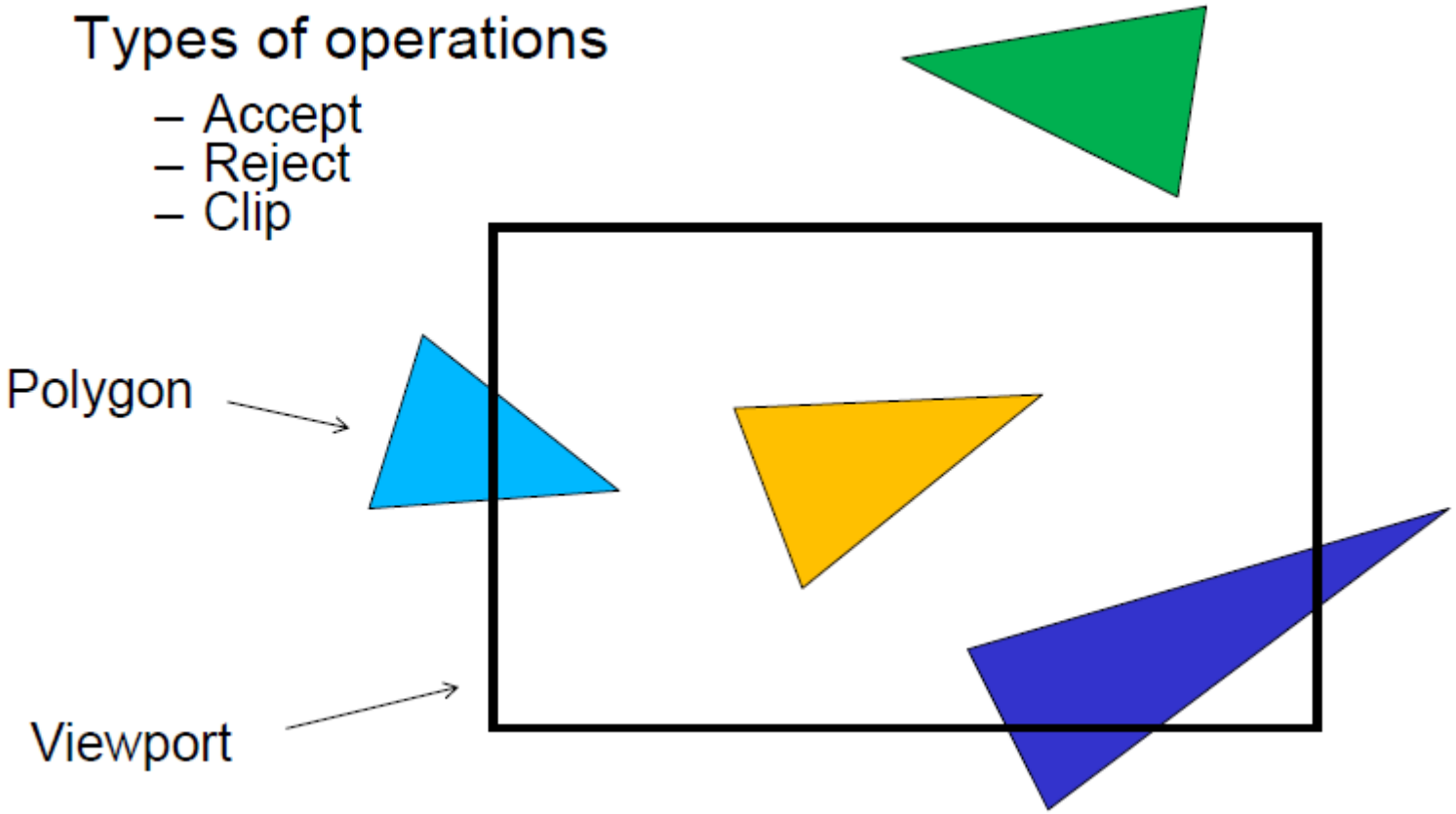


Brute force approach:

- Цонхны тал бүрээс илүү ирмэгийг хасах
- Огтлолцол бүрт нэг зүсэлт (үр дүн муу арга)

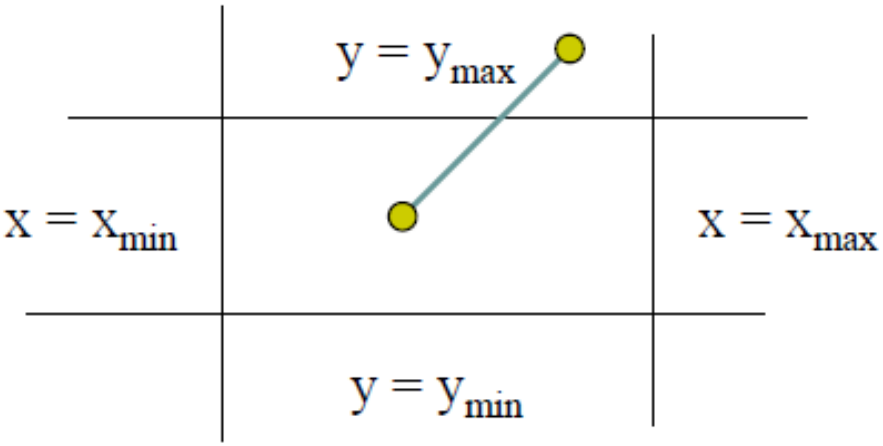


2D clipping



2D clipping

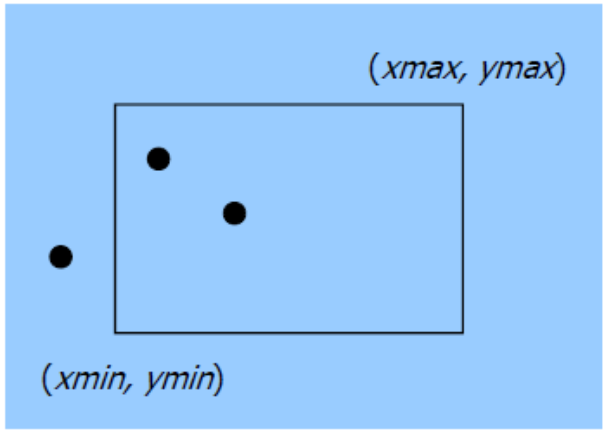
- Cohen-Sutherland clipping algorithm



Clipping points

- Цэгүүдийн байрлалыг тогтооно.
- Цонхны гадна, дотор байгааг олно.

```
If   (xmin <= x <= xmax)
and (ymin <= y <= ymax)
```



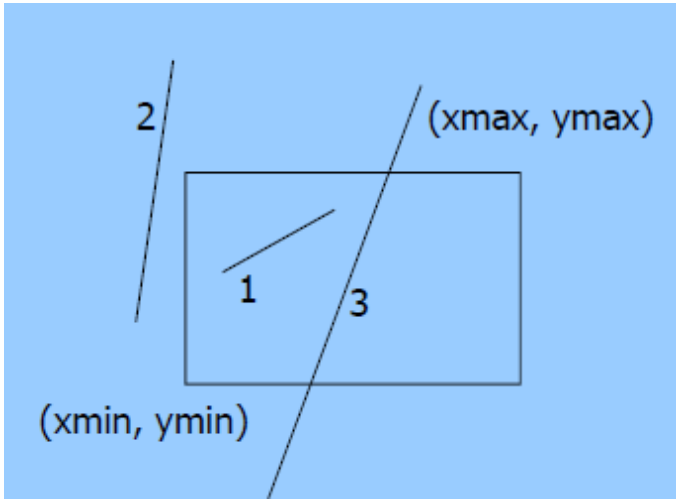
  - (x,y) – дотор талд
  - Эсрэг тохиолдолд – гадна талд

Clipping Lines

Case1: Бүх шулуун багтана

Case2: Бүх шулуун гадна байна.

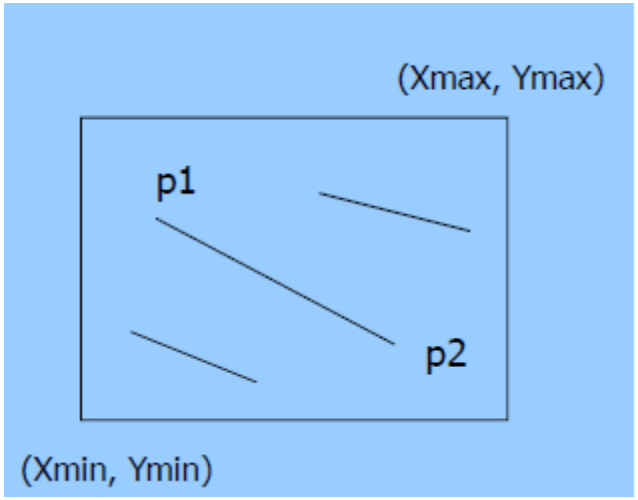
Case3: Зарим нь багтана, зарим нь гадаа



Clipping Lines: Trivial Accept

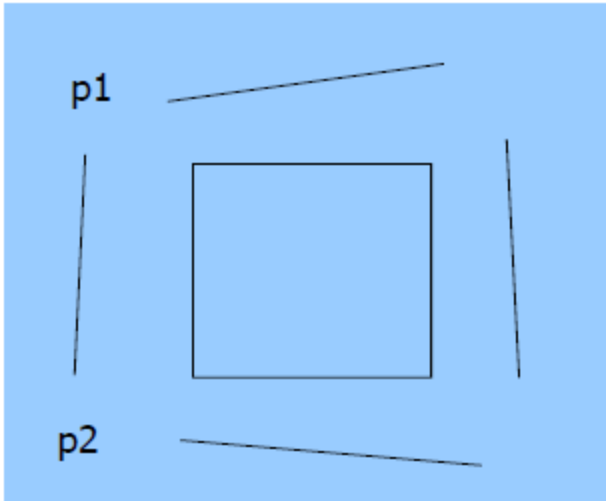
- Case1: Бүх шулуун багтана
- x, y утгуудыг тэгш өнцөгтийн x,y утгуудтай харьцуулна.
- **Үр дүн:** ердийн зөвшөөрөл(accept). Шулуунийг бүхэлд нь зурна.

Xmin <= P1.x, P2.x <= Xmax and
Ymin <= P1.y, P2.y <= Ymax



Clipping Lines: Trivial Reject

- Case 2: Бүх шулуун гадна байна.
- Reject.
- Don't draw line in

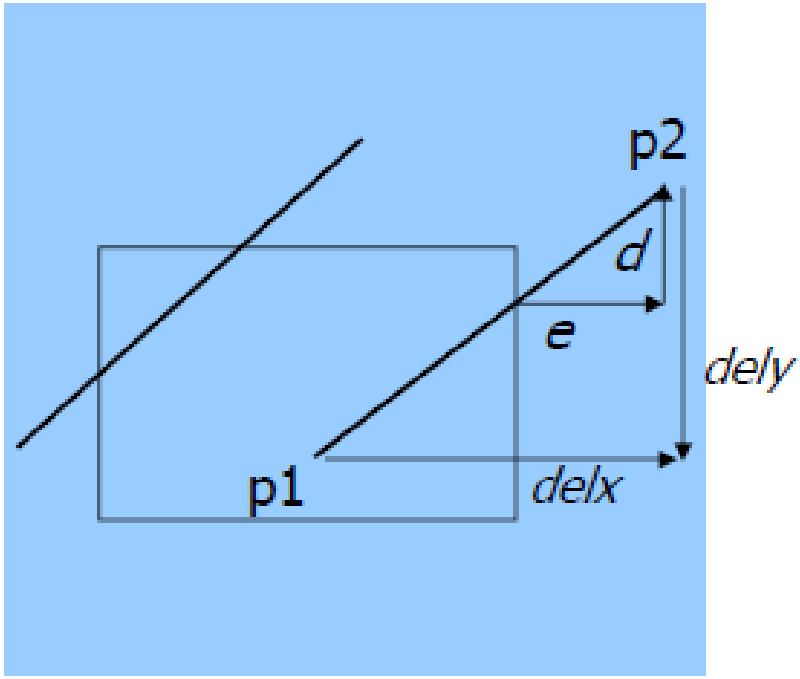


- *p1.x, p2.x <= Xmin* OR
- *p1.x, p2.x >= Xmax* OR
- *p1.y, p2.y <= ymin* OR
- *p1.y, p2.y >= ymax*

Clipping Lines: Non-Trivial Cases

- Case 3: Part in, part out

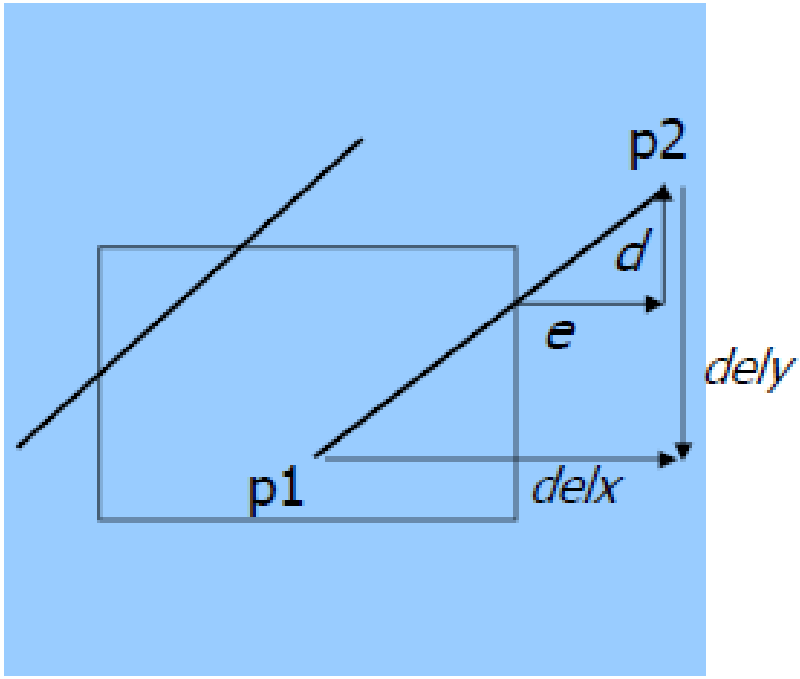
  Дотор агуулагдаж буй хэсгийг олох шаардлагатай.
- Гурвалжин ашиглан уртыг тооцож болдог.



$$\frac{d}{dely} = \frac{e}{delx}$$

Тооцоолол хийх

- (left, right, bottom, top) = (30, 220, 50, 240)



(a) p1 = (40,140), p2 = (100, 200)

(b) p1 = (20,10), p2 = (20, 200)

(c) p1 = (100,180), p2 = (200, 250)

$$\frac{d}{dely} = \frac{e}{delx}$$

Cohen-Sutherland pseudocode

```
int clipSegment(Point2& p1, Point2& p2, RealRect W)
{
do{
if(trivial accept) return 1; // whole line survives
if(trivial reject) return 0; // no portion survives
// chop
if(p1 is outside)
// find surviving segment
{
if(p1 is to the left) chop against left edge
else if(p1 is to the right) chop against right edge
else if(p1 is below) chop against the bottom edge
else if(p1 is above) chop against the top edge
}
```

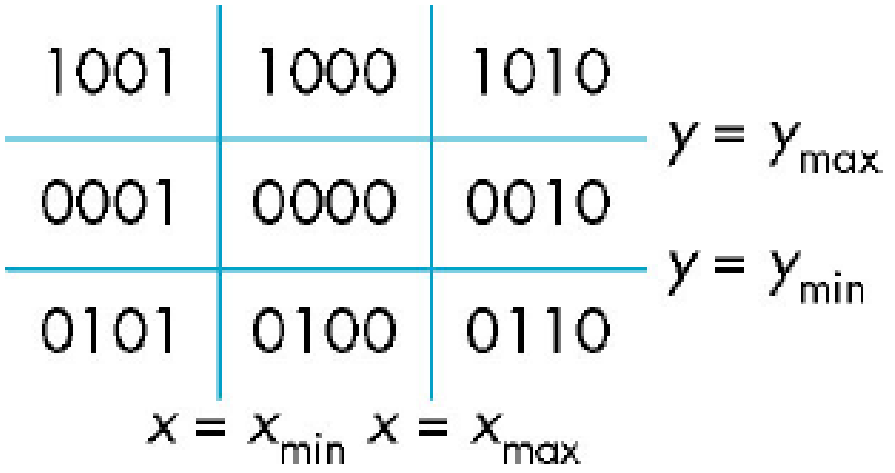
```
else // p2 is outside
// find surviving segment
{
if(p2 is to the left) chop against left edge
else if(p2 is to right) chop against right edge
else if(p2 is below) chop against the bottom edge
else if(p2 is above) chop against the top edge
}
}while(1);
}
```

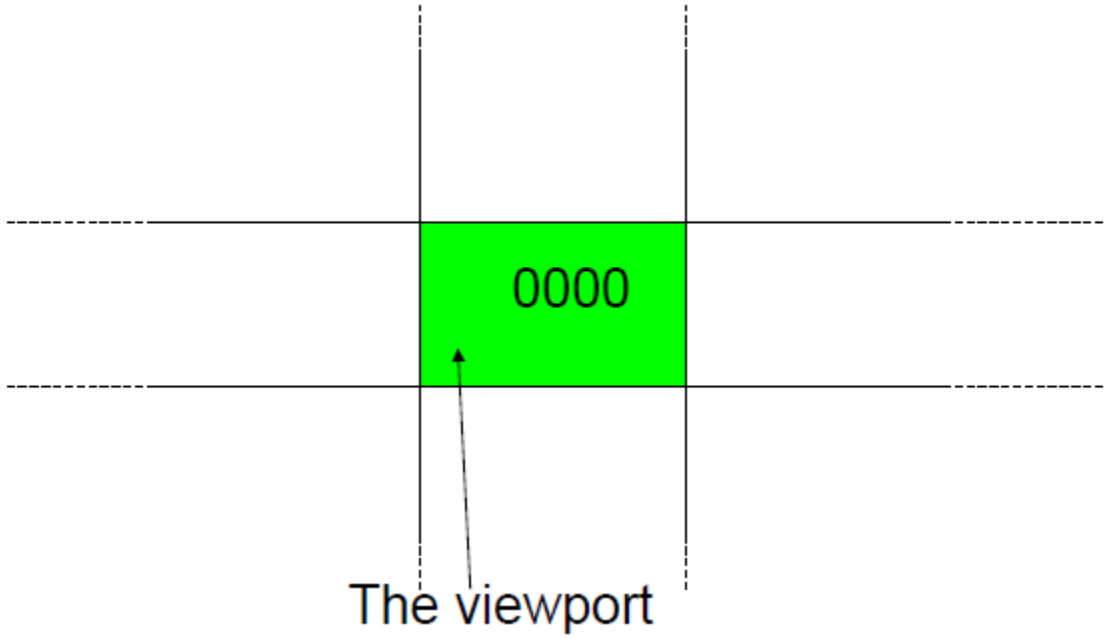
Үр дүнг ашиглан харьцуулатыг хурдасгах

- Endpoint бүрийг кодчилон доорх үр дүнгээс харьцуулн а. (9 талбар, 4 бит код)

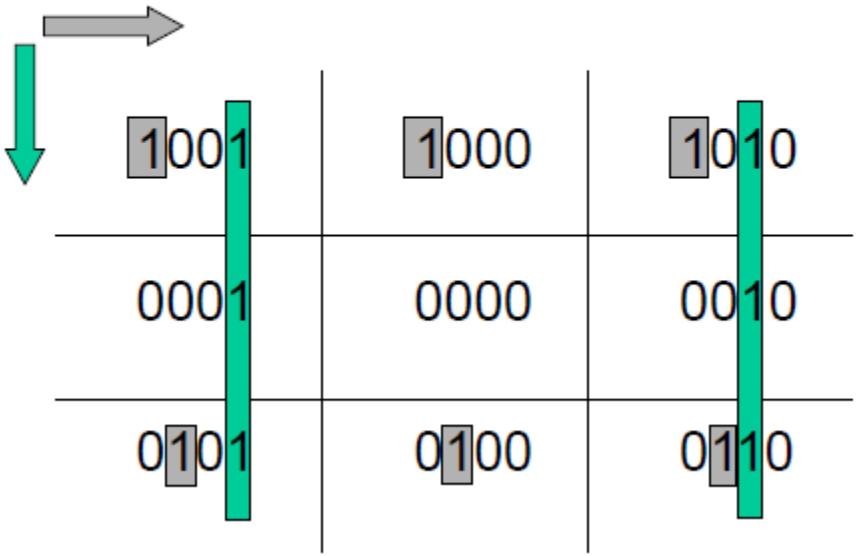
$$b_0 b_1 b_2 b_3$$

$b_0 = 1$ if $y > y_{max}$, 0 otherwise
$b_1 = 1$ if $y < y_{min}$, 0 otherwise
$b_2 = 1$ if $x > x_{max}$, 0 otherwise
$b_3 = 1$ if $x < x_{min}$, 0 otherwise



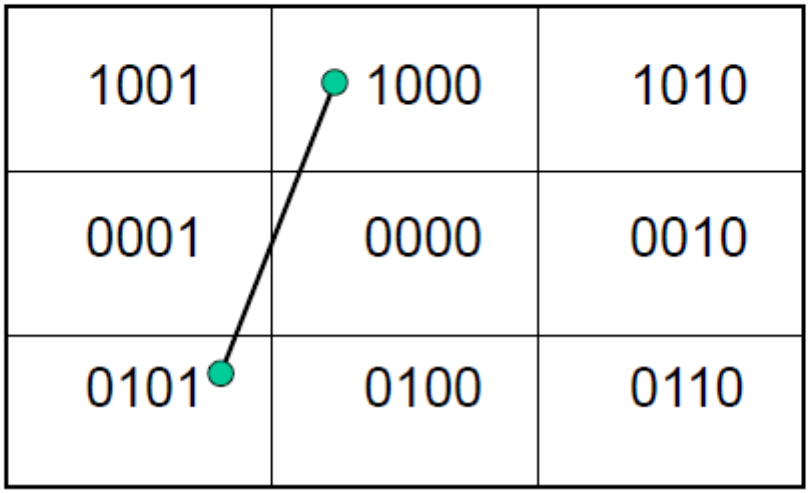

0000
The viewport

Each side corresponds to one bit in the codes (outcode)



The endpoints are assigned an outcode

– 1000 and 0101 in this case



The outcode $o_1 = outcode(x_1, y_1) = (b_0\, b_1\, b_2\, b_3)$ is easily assigned:

$$b_0 = \begin{cases} 1 & \text{if } y > y_{\max}, \\ 0 & \text{otherwise.} \end{cases}$$

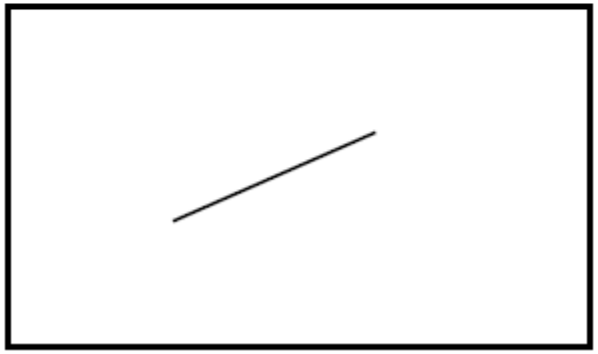
$$b_1 = \begin{cases} 1 & \text{if } y < y_{\min}, \\ 0 & \text{otherwise.} \end{cases}$$

$$b_2 = \begin{cases} 1 & \text{if } x > x_{\max}, \\ 0 & \text{otherwise.} \end{cases}$$

$$b_3 = \begin{cases} 1 & \text{if } x < x_{\min}, \\ 0 & \text{otherwise.} \end{cases}$$

$o_1 = o_2 = 0000$

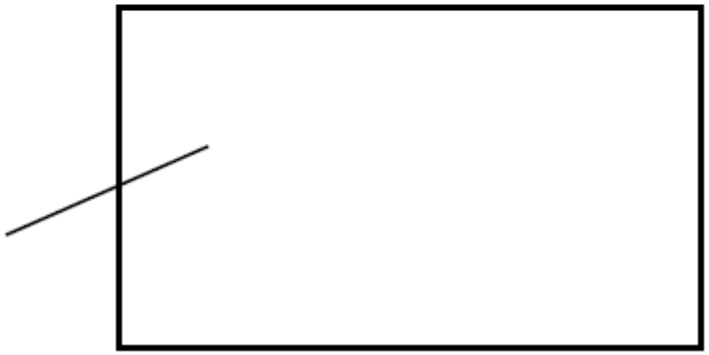
Both endpoints are inside the clipping window (Accept, no clipping needed)



o_1!=0000, o_2=0000; or vice versa

One endpoint is inside and the other is outside

- The line segment must be shortened (clipped)

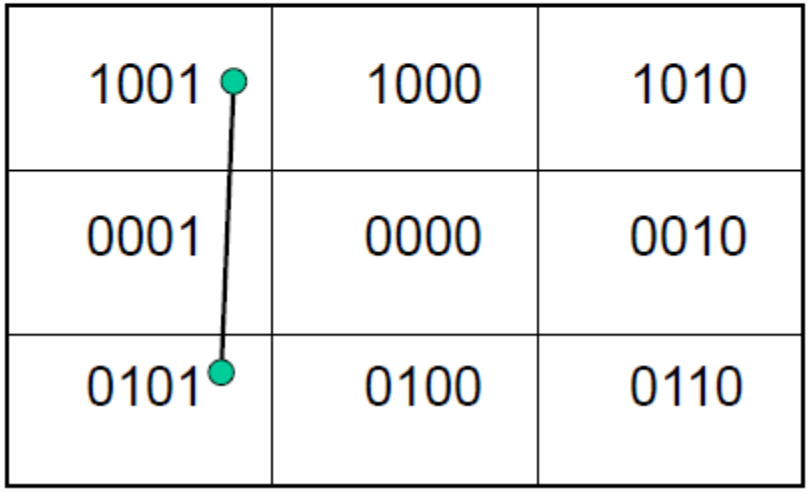


*o_1&o_2!=0000 (Bitwise **and** operator)*

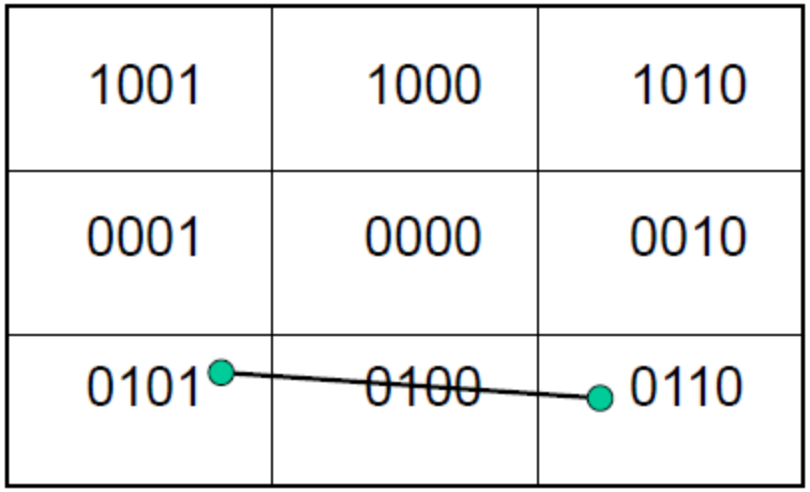
Both endpoints are on the same side of the clipping window

– Trivial Reject

*$O_{1=}$ 1001, $O_{2=}$ 0101 bitwise **and** operator gives:*
1001 & 0101 = 0001 != 0000, both ends are on the same side of the clipping window ---> reject!

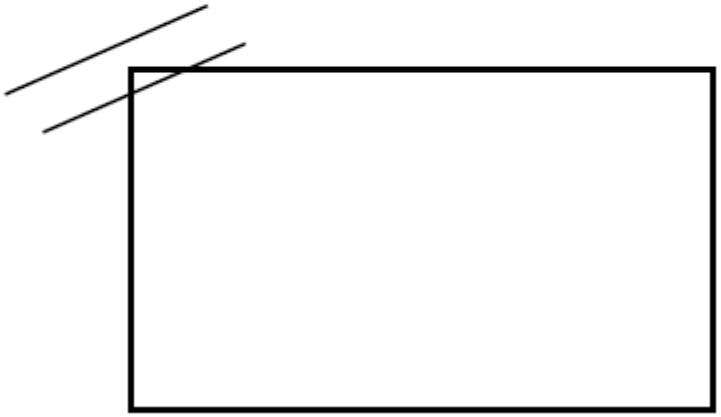


*$O_{1=}$ 0101, $O_{2=}$ 0110 bitwise **and** operator gives:*
0101 & 0110 = 0100 != 0000, both ends are on the same side of the clipping window ---> reject!



o_1&o_2=0000 (Given o_1!=0000 and o_2!=0000)
Both endpoint are outside but outside different edges

- The line segment must be investigated further



*$O_{1=}$ 0101, $O_{2=}$ 1000 bitwise **and** operator gives:*
0101 & 1000 = 0000, part of the line could be inside the viewport ---> further investigation needed!