

3D Object Representation

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Intended Learning Outcomes

- Understand the concept of **standard graphics object**
- Able to mathematically manipulate and program in OpenGL two types of planar representation: tables and **mesh**
- Distinguish the **parametric** and **non-parametric** equations and the advantage of using the former in computer
- Able to mathematically manipulate and program in OpenGL quadrics and super-quadrics

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Standard Graphics Object

- **standard graphics object = a set of (planar) polygons**

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- Complicated objects consisting of many polygons
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- Dedicated hardware are designed for rendering of standard graphics objects.
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Two methods for storing standard graphics objects

- Method 1: use table (vertex, edge, polygon, attribute)

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■ Method 2: Quadrilateral Mesh

- ❑ A $n \times m$ array of vertex positions (X, Y, Z)
- ❑ Represent a surface of $(n-1) \times (m-1)$ quadrilaterals
- ❑ Each quadrilateral may be further subdivided into two triangles
- ❑ Two ways to create a quadrilateral mesh
 - Way 1: By specifying an edge
 - Way 2: By 3D digitizer

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3-D scanner

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3D scanner is available in CityU Library:

<http://www.cityu.edu.hk/lib/about/facility/3d/index.htm>

Glut functions

- *glutWire* as wireframe
 - *glutSolid* as fill area polygon patches
- glutSolidCu* <https://eduassistpro.github.io/>
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- Tetrahedron, Cube, Octahedron,
Dodecahedron, Icosahedron

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Mathematical Concepts for Plane

- Plane

$$aX + bY + cZ + d = 0$$

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- Only 3 parameters define the plane, the fourth can be set to 1 or 0
- $d = 1$ does not pass through $(0, 0, 0)$
- $d = 0$ pass through $(0, 0, 0)$

Normal

- Important concept in lighting and shading
- Normal vector
 - vector \perp to t
 - “Unit vector” <https://eduassistpro.github.io/>
- Solving for Normal
 - Normal $\mathbf{n} = (a, b, c)$
 - Select 3 vertices on the plane **V1, V2, V3**
$$\mathbf{n} = (V2 - V1) \times (V3 - V1)$$

Distinguishing “Inside” from “Outside”

- Useful for “collision detection”

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- Use (a, b, c

$aX+bY+cZ$ <https://eduassistpro.github.io/>

$= 0$ On the plane
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 < 0 side

- Use **V1, V2, V3**

V1, V2, V3 selected CCW \Rightarrow Outside
CW \Rightarrow Inside

Inside-Outside Test

- To determine whether a pixel p is inside or outside an object S
- Send a ray $p + t v$ which starts at the pixel, t is a scalar, v is an arbitrary direction vector
- Find all non-degenerate intersections between the ray and S
- If the number of intersections is odd, p is inside (outside) S
- It is not easy to check non-degenerate intersections. One can solve this problem by sending out n rays in random directions and then use majority voting

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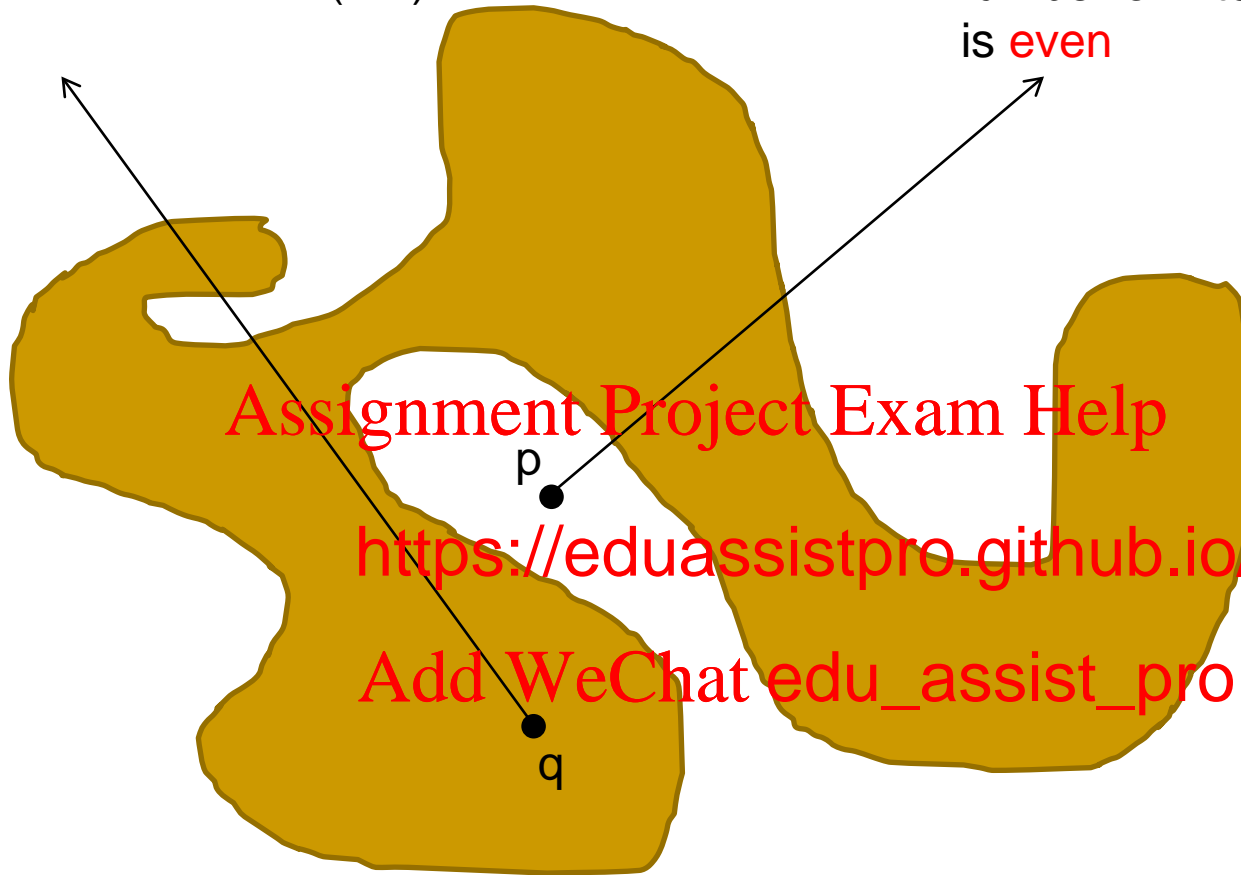
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[†] a degenerate intersection is one which the ray grazes the surface

Point q is **inside** as the
number of intersections (= 3)
is **odd**

Point p is **outside** as the
number of intersections (= 2)
is **even**



The yellow object is depicted as a 2D object but the
technique can be applied to any n -dimensional object ($n > 2$)

Superquadrics

- 2D QUADRICS (conic section)

$$aX^2 + bY^2 + cXY + dX + eY + f = 0$$

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- 3D QUADRICS

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$$aX^2 + bY^2 + cZ^2 + dXY + eXZ + fYZ + gX + hY + iZ + k = 0$$

In 2D,

- Circle $X^2 + Y^2 = r^2$

- Ellipse $\frac{X^2}{a^2} + \frac{Y^2}{b^2} = 1$

- Parabola

$$Y^2 = 4aX$$

- Hyperbola $X^2 - Y^2 = r^2$

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In 3D

- Sphere

$$X^2 + Y^2 + Z^2 = r^2$$

- Ellipsoid

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$$\left(\frac{X}{a}\right)^2 + \left(\frac{Y}{b}\right)^2 + \left(\frac{Z}{c}\right)^2 = 1$$

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- Paraboloid

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- Hyperboloid

?

(ans. to be discussed in tut.)

“Super”-quadrics

- Introduce to additional parameters s1 and s2
- Allow continuous transformation from “circle” to “square” (align)
- Example (2D)

$$\left(\frac{X}{a}\right)^{\frac{2}{s}} + \left(\frac{Y}{b}\right)^{\frac{2}{s}} = 1$$

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Super-ellipsoid

$$\left[\left(\frac{X}{r_x} \right)^{2/s_2} + \left(\frac{Y}{r_y} \right)^{2/s_2} \right]^{s_2/s_1} + \left(\frac{Z}{r_z} \right)^{2/s_1} = 1$$

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Non-parametric and Parametric forms

■ Non-parametric form

- $Z = f(X, Y)$ or $f(X, Y, Z) = 0$

- Used in mathematics

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■ Parametric form

- Introduced two additional parameters u, v

- $X = f1(u, v)$ $Y = f2(u, v)$ $Z = f3(u, v)$

- Used in CG

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Parametric form of the super-ellipsoid

$$\left[\left(\frac{X}{r_x} \right)^{2/s_2} + \left(\frac{Y}{r_y} \right)^{2/s_2} \right]^{s_2/s_1} + \left(\frac{Z}{r_z} \right)^{2/s_1} = 1 \quad \text{Non-parametric}$$

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$$X = r_x \cos^{s_1} \phi \cos^{s_2} \theta$$

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$$Y = r_y \cos^{s_1} \phi \sin^{s_2} \theta$$

$$Z = r_z \sin^{s_1} \phi$$

OpenGL functions

- Does not have superquadrics function
- Can display sphere, cone, cylinder
- Quadrilater

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glutWireSphere (r, nLo Add WeChat edu_assist_pro *nLatitudes)*

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Generation of complicated shapes

- Complicated shapes can be generated using quadrilateral mesh and parametric form
- Two examples
 - Generalize <https://eduassistpro.github.io/>
 - Generalized Symmetry

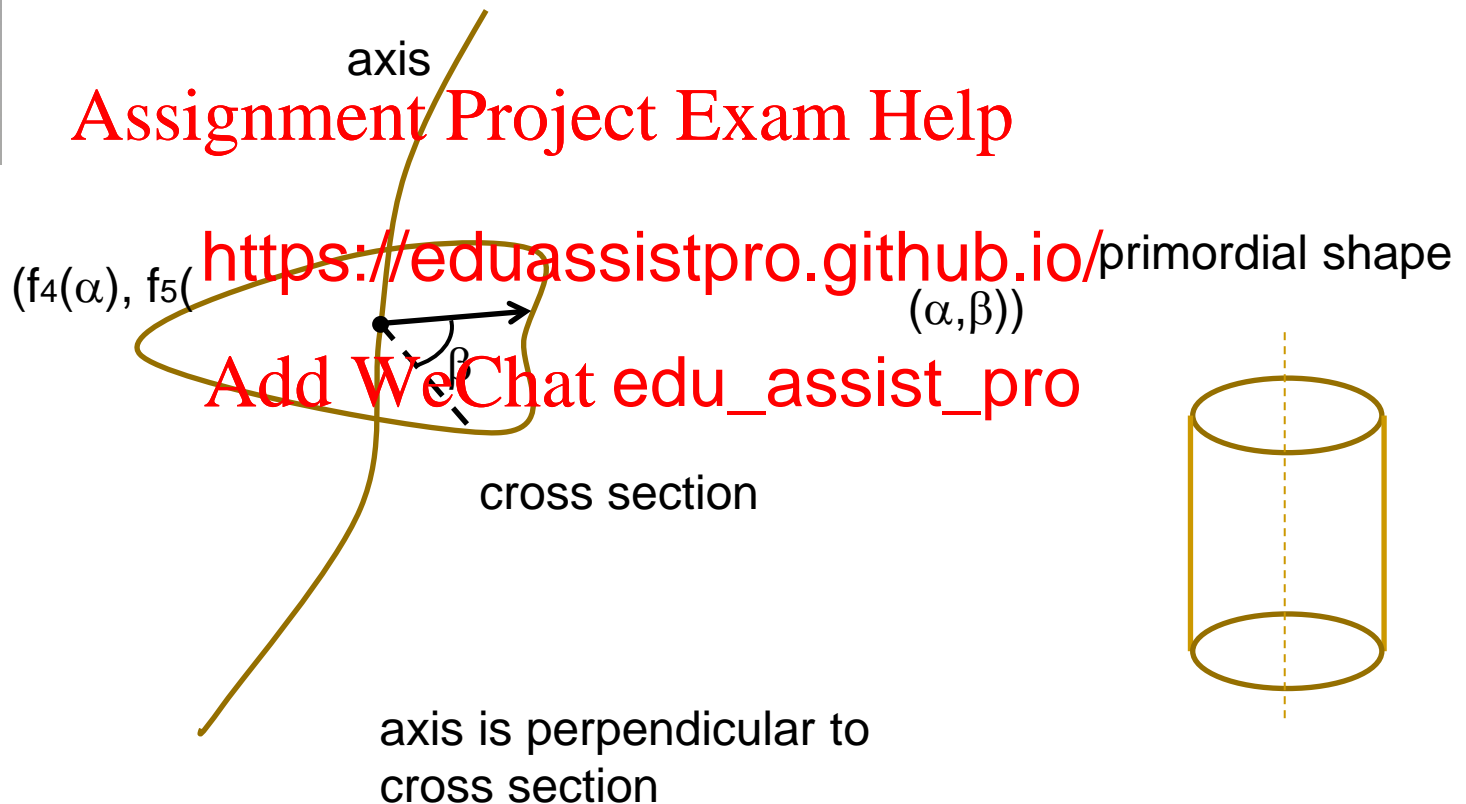
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Generalized Cylinder



real life example



quadrilateral mesh parameterized by α and β

A single, vibrant green maple leaf is shown against a plain white background. The leaf has a classic palmate shape with five distinct lobes. Each lobe is pointed and has a finely serrated or toothed margin. The venation is clearly visible, with a central midrib and secondary veins branching out to the tips of the lobes. The leaf is attached to a short, reddish-brown petiole (stem) that tapers slightly towards the base of the leaf. The overall appearance is that of a healthy, young leaf, possibly from a sugar maple or a similar species.

$$\mathbf{b}(\mathbf{f}_4(\alpha),$$

primordial shape

A diagram of an isosceles triangle with a dashed vertical line passing through its apex and the midpoint of its base, representing its axis of symmetry.

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References

Ex: Practice using the index

For example, text

- OpenGL Line Functions Sec. 4-4
- Superquadric <https://eduassistpro.github.io/>
- Parametric and non-parametric forms: A-8, A-9