Tribhuvan University
Institute of Science and Technology
Bachelor of Science in
Computer Science and Information Technology

3RD Semester

CSC209: Computer Graphics

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U6: Solid Modeling 4 Hrs

6.1 Sweep ,Boundary and Spatial-Partitioning Representation

6.2 Binary Space Partition Trees (BSP)

6.3 Octree Representation

Solid Modeling

The common 3D models are:

1. Wireframe - Uses lines, arcs and curves, as if the object shape were made with pieces of wire.

2. Surface - Uses surfaces to show the outside of the model, as if it were made from pieces of stretchy paper.

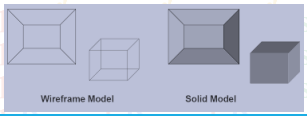
It's hollow inside, but looks realistic on the outside.

3. Solid - Uses solid material throughout, not hollow.

Solid Modeling

Solid model of an object is a more complete representation than its surface (wireframe) model.

It provides more topological information in addition to the geometrical information which helps to represent the solid unambiguously.



Solid Modeling

- Solid modeling (or modeling) is a consistent set of principles for mathematical and computer modeling of three-dimensional solids.
- It is distinguished from related areas of geometric modeling and computer graphics by its emphasis on physical fidelity.
- Implementation of solid object unambiguously (clearly), represents only one object
- In the solid Modeling, the solid definition include **vertices(nodes), edges, surfaces, weight, and volume.**
- The model is a complete, valid and unambiguous representation of a precisely enclosed and filled volume

Solid Modeling

- **Complete**:
  points in space can be classified. (inside/outside).
- **Valid**:
  Vertices, edges, faces are connected properly.
- **Unambiguous**:
  there can be only one interpretation of object.

Geometry vs Topology:

Geometry:

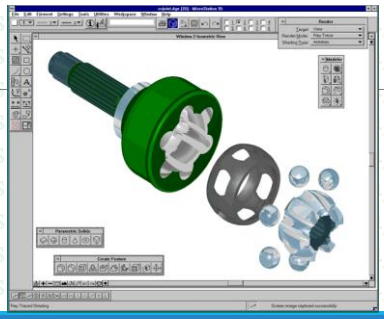
Metrics and dimensions of the solid object.

Location of the object (x,y,z) in a chosen coordinate system.

Topology:

Combinational information like connectivity, associativity, and neighborhood information.

Invisible relationship information.



Properties of Solid models

- Bounded boundary limits and contain the interior of the solid
- Homogenously 3D no dangling edges or faces presented boundary is always in contact with the interior of the solid
- Finite solid is not infinite in size can be described by a limited amount of information

Advantages of solid Models

- Unlike wireframe and surface representations which contain only geometrical data, the solid model **uses topological information** in addition to the **geometrical information** to represent the object **unambiguously and completely**.
- Solid models results in accurate design, helps to further the goal of CAD/CAM like CIM.
- Flexible manufacturing leading to better automation of the manufacturing process.

common representations in solid modeling

1. Spatial Enumeration:

In this simplest form of 3D volumetric raster model, a section of 3D space is described by a matrix of evenly spaced cubic volume elements called voxels.

2. Cell Decomposition:

This is a hierarchical adaptation of spatial enumeration. 3D space is sub-divided into cells. Cells could be of different sizes. These simple cells are glued together to describe a solid object.

common representations in solid modeling

3. Boundary Representation:

The solid is represented by its boundary which consists of a set of faces, a set of edges and a set of vertices as well as their topological relations.

4. Sweep Methods:

In this technique a planar shape is moved along a curve. Translational sweep can be used to create prismatic objects and rotational sweep could be used for axisymmetric components.

common representations in solid modeling

5. Primitive Instancing:

This modeling scheme provides a set of possible object shapes which are described by a set of parameters. Instances of object shape can be created by varying these parameters.

6. Constructive Solid Geometry (CSG):

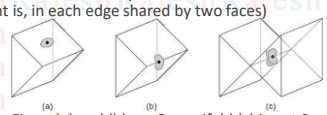
Primitive instances are combined using Boolean set operations to create complex objects

Boundary representation:

The solids are described by its boundary surface. Uses the description by vertices, edges and faces.

The most common representation is the boundary polygons.

Will be considered only with solid border 2-manifolds(wherever the point is, in each edge shared by two faces)

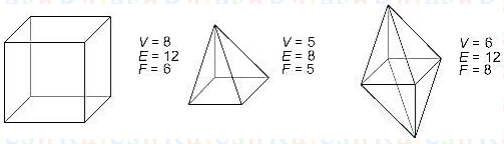


Figure(a) and (b) are 2-manifold (c) is not 2-manifold

Boundary representation:

Euler's Formula

F + V – E = 2



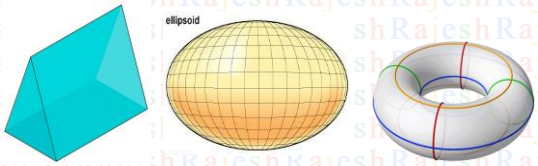
Boundary representation:

Name		Faces	Vertices	Edges	F+V-E
Tetrahedron		4	4	6	2
Cube		6	8	12	2
Octahedron		8	6	12	2
Dodecahedron		12	20	30	2
Icosahedron		20	12	30	2

Sweep Representation

- It creates solid by moving a 2D shape (triangle, rectangle, polygon etc.) according to predefined rule (translating, rotating).
- It is used to construct 3D object from 2D shape that have some kind of symmetry.
- For example, a prism can be generated using a translational sweep and rotational sweeps can be used to create curved surfaces like an ellipsoid or a torus.
- There are two types sweep representation:
  1) Translational Sweep
  2) Rotational Sweep

Sweep Representation



Translational Sweep:

- In translational sweeps, the 2D shape is swept along a linear path normal to the plane of the area to construct three dimensional object.
- To obtain the wireframe representation we have to replicate the 2D shape and draw a set of connecting lines in the direction of shape, as shown in the figure

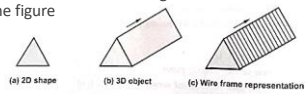


Fig. (8) Translational sweep

Rotational Sweep

- In rotational sweeps, the 2D shape is rotated about an a axis of rotation specified in the plane of 2D shape to produce three dimensional object.

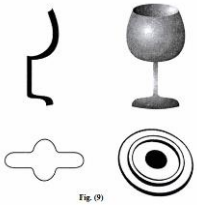
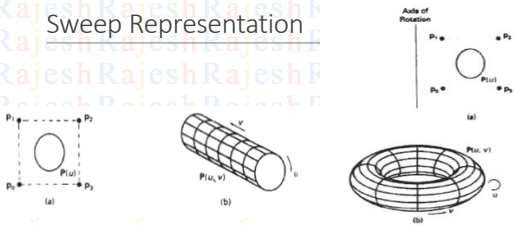


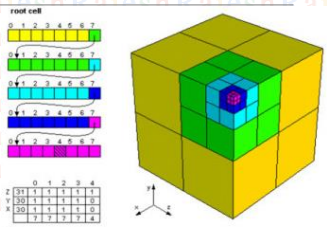
Fig. (9)

Sweep Representation



Spatial Partitioning Representation:

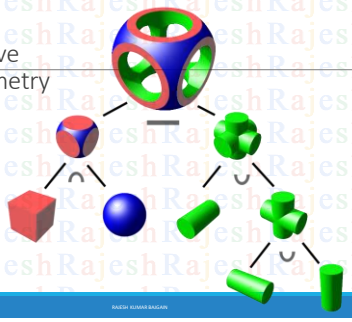
- A solid is represented as a collection of adjoining non-intersecting object.
- For example: Octree



Constructive Solid Geometry (CSG)

- A CSG model is based on the topological notion that a physical object can be divided into a set of primitives (basic elements or shapes) that can be combined in a certain order following a set of rules (Boolean operations) to form the object.
- Each primitive is bounded by a set of surfaces; usually closed and orientable.
- It is based on the idea of providing a set of predefined object types such as cubes, cone, sphere etc.
- A solid model is created by retrieving primitive solids and performing Boolean operations.

Constructive Solid Geometry (CSG)



Constructive Solid Geometry (CSG)

Three types of Boolean operations:

o Union (join): the operation combines two volumes included in the different solids into a single solid.

o Subtract (cut): the operation subtracts the volume of one solid from the other solid object.

o Intersection: the operation keeps only the volume common to both solids.

Binary Space Partitioning Tree (BSP)

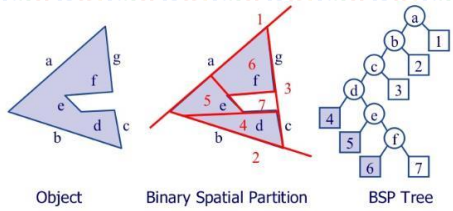
Binary space partitioning is a generic process of recursively dividing a scene into two until the partitioning satisfies one or more requirements.

- At each step, the space is divided by a plane of arbitrary position and orientation.

- Each internal node of the tree is associated with a plane and has two child pointers (one for inside the polygon and the other to the outside).

- If the subspace is homogenous (fully indoors and outdoors), cease to be divided.

Binary Space Partitioning Tree (BSP)



Octree Representation (Solid-object representation)

This is the space-partitioning method for 3D solid object representation.

Octrees are hierarchical tree structures that describes each region space as nodes.

They are used to represent solid objects in some graphics system.

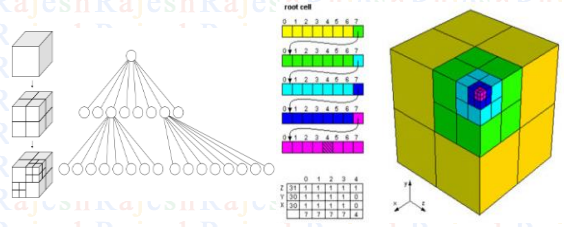
- Medical imaging and other applications that require displays of object cross sections commonly use octree representation. E.g. CT-scan.

Octree Representation (Solid-object representation)

Octrees are used to partition a 3D space by recursively subdividing it into eight octants.

Octant subdivisions continue until the region of space contains only homogeneous octants.

- Octrees are often used in 3D graphics and 3D game engines.



Octree Representation (Solid-object representation)

Advantages:

- It provides a convenient representation for storing information about object interiors.

- They can represent arbitrary shapes and that we can quickly analyze what is present at a specific position in space.

Disadvantages:

- Imprecise representation, high storage demands and complex transformation operations.

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