

## Primitives

The term **geometric primitive** in [computer graphics](#) and [CAD](#) systems is used in various senses, with the common meaning of the simplest (i.e. 'atomic' or irreducible) geometric objects that the system can handle (draw, store). Sometimes the [subroutines](#) that draw the corresponding objects are called "geometric primitives" as well. The most "primitive" primitives are point and straight line segment, which were all that early [vector graphics](#) systems had.

In [constructive solid geometry](#), primitives are simple [geometric shapes](#) such as a [cube](#), [cylinder](#), [sphere](#), [cone](#), [pyramid](#), [torus](#).

Modern [2D computer graphics](#) systems may operate with primitives which are lines (segments of straight lines, circles and more complicated curves), as well as shapes (boxes, arbitrary polygons, circles).

A common set of two-dimensional primitives includes lines, points, and [polygons](#), although some people prefer to consider triangles primitives, because every polygon can be constructed from triangles. All other graphic elements are built up from these primitives. In three dimensions, triangles or polygons positioned in three-dimensional space can be used as primitives to model more complex 3D forms. In some cases, curves (such as [Bézier curves](#), [circles](#), etc.) may be considered primitives; in other cases, curves are complex forms created from many straight, primitive shapes.

Commonly used geometric primitives include:

- [points](#)
- [lines](#) and [line segments](#)
- [planes](#)
- [circles](#) and [ellipses](#)
- [triangles](#) and other [polygons](#)
- [spline curves](#)

Note that in 3D applications basic geometric shapes and forms are considered to be primitives rather than the above list. Such shapes and forms include:

- [spheres](#)
- [cubes](#) or [boxes](#)
- [toroids](#)
- [cylinders](#)
- [pyramids](#)

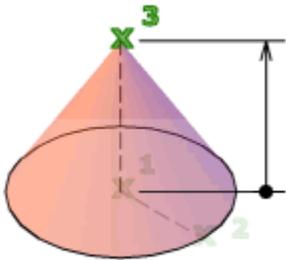
These are considered to be primitives in 3D modelling because they are the building blocks for many other shapes and forms. A 3D package may also include a list of extended primitives which are more complex shapes that come with the package. For example, a [teapot](#) is listed as a primitive in [3D Studio Max](#).

## 3D Modeling Series 2: Primitives

11/09/2009 **Orhan Toker** in [3D](#) , [Solid Modeling](#) labels. [4 yorum](#)

[AutoCAD 2007 & Higher versions, Level: Advanced]

Hello Daily AutoCAD readers,



In the second article of my series of articles about 3D modeling, I will explain about the primitive solid entities. In Fig. 1, you can see all of these entities together. Instead of explaining how each entity is drawn in AutoCAD, I will give you some figures that show the physical structure and what are the variables that AutoCAD needs to draw these entities.

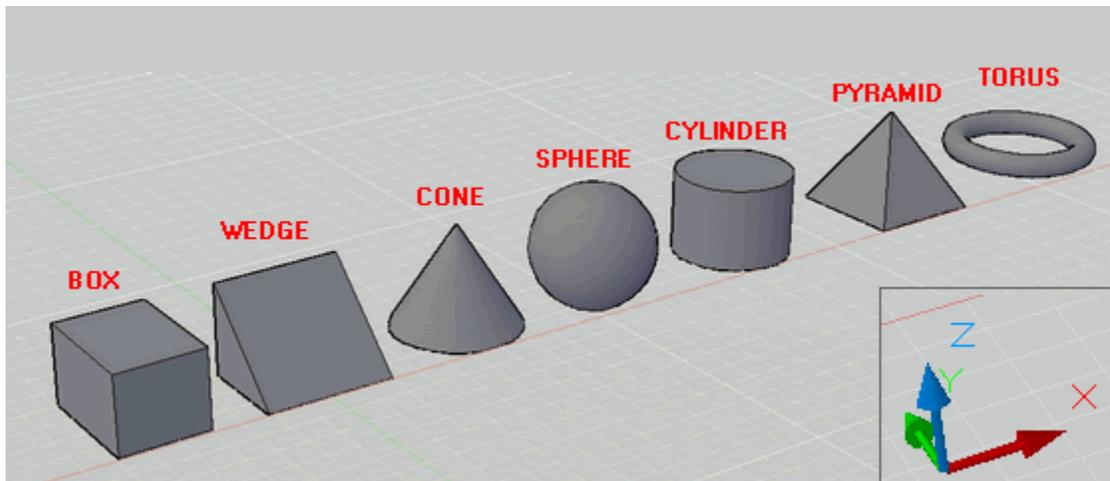


Fig.1

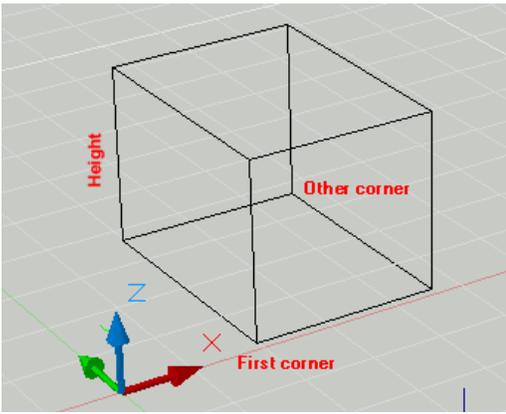


Fig.2 Box

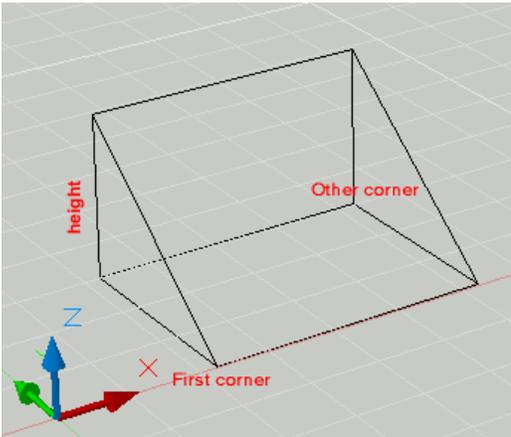


Fig.3 Wedge

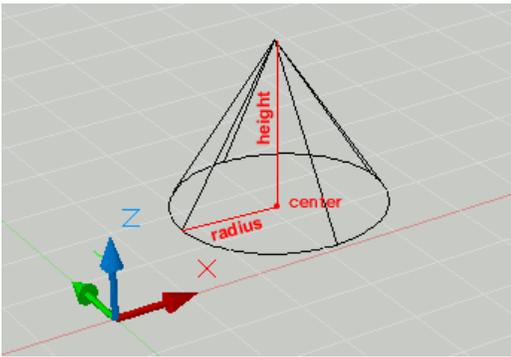


Fig.4 Cone

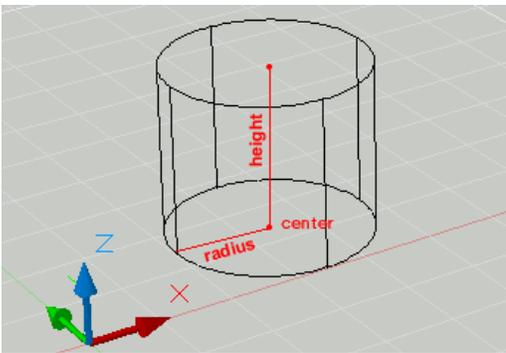


Fig.5 Cylinder

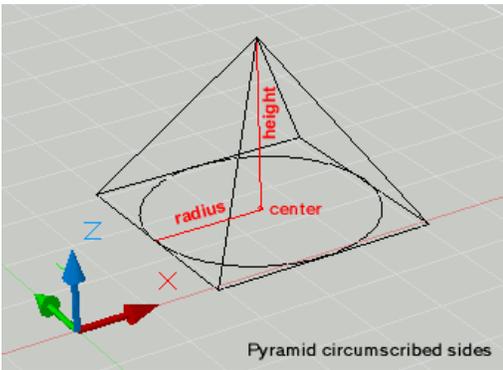


Fig.6 Pyramid

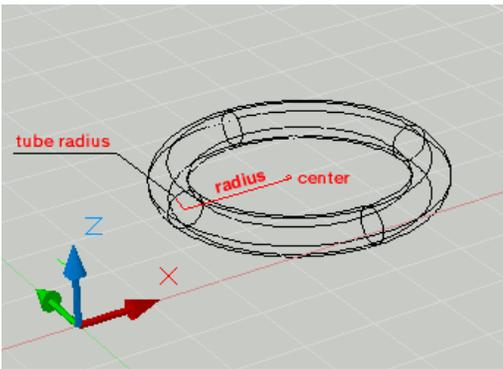


Fig.7 Torus

These are the primitive shapes that you can use when making 3D solid modeling. You may also remember these shapes from high school. You can call all of these shapes can be drawn by calling from **DASHBOARD** that we have placed on screen as described in the previous lesson. I will explain command options in detail in my future articles. So, I am giving only the representing figures.

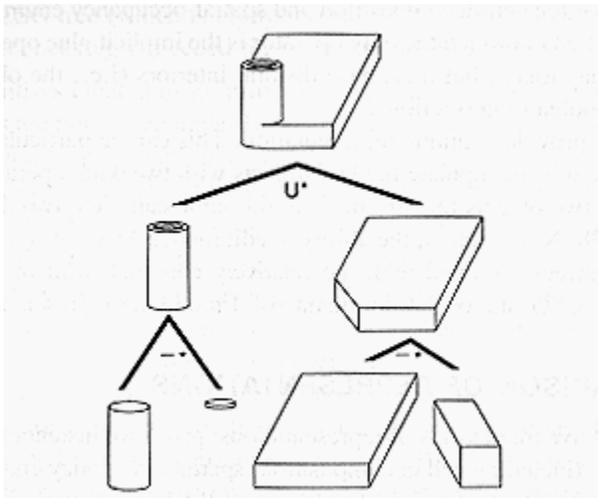
## SOLID MODELING

In surface modeling, a three-dimensional object (a cube, for example) is represented as a set of six separate faces. Even though the faces might be grouped to make a single object, in a surface model there is no internal representation of the object as such. With a solid modeling program, on the other hand, an object is represented internally as a single object made up connected faces.

Solid modeling is particularly useful for engineering applications. With a solid modeling representation it is possible to calculate physical properties of the object (e.g. mass or inertia) and to check for object interference. It is also useful to generate instructions to create physical models with computer-controlled machinery (CAD-CAM).

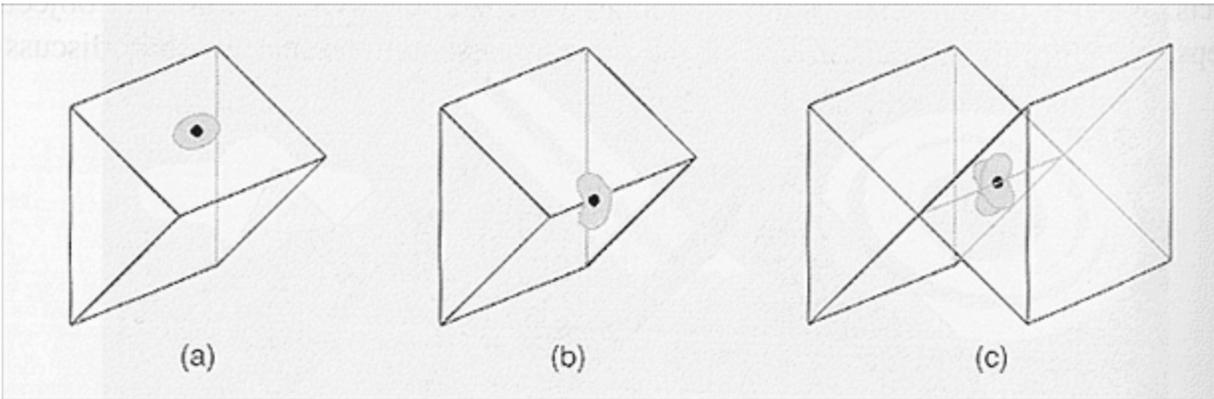
The intrinsic limitations of solid modeling, mostly due to the large data structures, limits its use to the creation of relatively small objects. Partly because of that reason, solid modeling is used in architecture mostly in the conceptual stages of a design, when this can be represented as a set of volumes. The use of solid modeling to create detailed building models is problematic, not only because of the limitations of the tool but also because of the established professional practices in the building industry. Nevertheless, CAM applications have been also applied to the construction of buildings or building components.

In CONSTRUCTIVE SOLID GEOMETRY, the process to create a solid as a combination of primitives and operations is reflected in a tree structure. This form of solid representation allows to edit existing solids by modifying a node of the tree (a primitive or an operation). As a result, the whole sequence of operations is recalculated automatically to generate the new solid (the solid modeling program used by AutoCAD 12 included this sort of solid representation).



*From Foley, Van Dam and alt. Computer Graphics. Principles and Practice. Addison-Wesley, 1991.*

The representation of the solid has to be **unambiguous**, that is to say, it should correspond to only one solid. It also has to avoid to represent **impossible** solids. What an impossible solid might be depends on the representation. In some systems, a solid in which an edge is shared by more than two faces would be an impossible solid (Figure c).



From Foley, Van Dam and alt. *Computer Graphics. Principles and Practice. Addison-Wesley, 1991.*

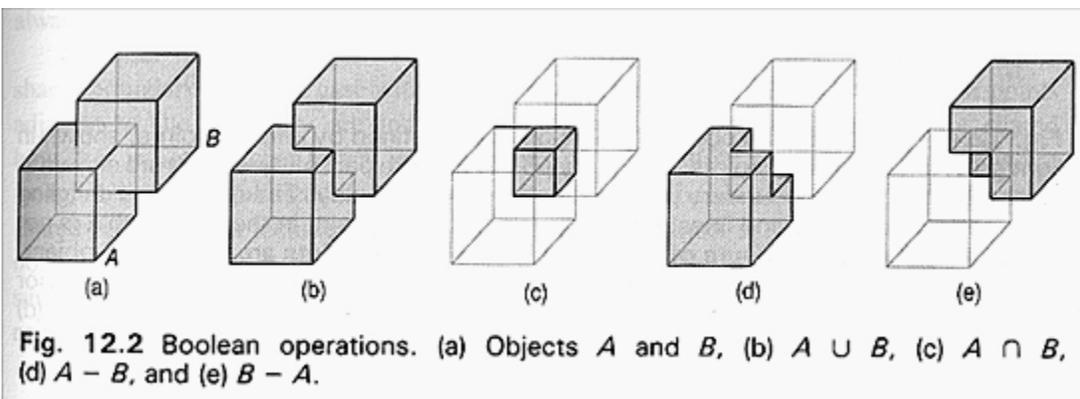
## SOLID PRIMITIVES

Solid objects can be generated in different ways:

- SWEEPING a two dimensional entity. This is a similar operation as the one used to generate 3d surface objects. (see [3d surface primitives](#))
- PRIMITIVE INSTANTIATION, inserting an instance of a given vocabulary of solid primitives. This is a particular implementation of the most generic instantiation technique (see [INSTANTIATION](#)). Typically, the parameters of the instance can be edited.
- combining existing solids with Boolean OPERATORS. The resulting object is a solid which can be used to create new solids.

## BOOLEAN OPERATORS

The power of solid modeling derives not only from its internal representation but mostly from the set of boolean operations that are used to create new solids from existing ones. The operators are the same as in set theory: union, subtraction (non-commutative) and intersection.



From Foley, Van Dam and alt. *Computer Graphics. Principles and Practice. Addison-Wesley, 1991.*

## SOLID MODELING: EXAMPLES

## AUTOCAD

In AutoCAD 12, the solid modeling tool was based on a CSG representation. The solid modeling that is included in versions 13 and 14 uses boundary representation.

In version 13, the solid operations are divided into different menus. The menu DRAW: SOLIDS contains the primitives and the editing operations. The menu CONSTRUCT contains the booleand operations.



Solid objects can be created from a set of primitives (box, sphere, cylinder, cone, wedge and torus) or sweeping two dimensional elements (extrude, revolve). Extrude works also with closed plines, which can be extruded along complex paths. There is another sort of solid primitives called REGIONS (in menu CONSTRUCT), which are basically two-dimensional solids. A REGION is created after an existing two-dimensional entity, for example, a closed polyline.

The editing operations for solids in AutoCAD 13 are rather limited. Since the CSG representation was abandoned, there is no possibility of editing a composite solid. The only way to transform it is to combine it with other solids, or to use the SLICE operator. With SLICE, a plane is used to cut a solid into separate pieces. SECTION produces a cross section (polyline) of the solid through the specified plane.

Apart from the standard Booleand operations (union, intersection, subtraction), there is a fourth one called INTERFERENCE, to be found in the DRAW: SOLIDS menu. Interference is an intersection operator that preserves the original solids.

## 3D PRIMITIVES

In this section, we will consider only surface modeling. Solid modeling is addressed in a separate section.

**Polygon meshes** and **polyhedra** are the geometric figures that are created with a surface modeler. A polygon mesh is a collection of edges, vertices and polygons connected in such a way that each edge is shared by at most two polygons. Polyhedra are volumetric solids, such as the cube or a sphere, represented as facets.

Much of the early work in computer graphics was put in the finding of mathematical representations for curves and surfaces, to make computer models of industrial products like cars or planes. The **Coons** patch, for example, is a technique for creating surfaces that interpolate boundary curves. Different techniques were developed to represent mathematically free curves or **splines**. A B-Spline is a curve defined by a set of control points. The Bézier curve, is a B-spline defined by four control points: two endpoints and two other that control the endpoint tangent vectors that are not necessarily on the curve.

Three-dimensional surface objects can be created from 2d entities, by means of a SWEEPING operation. For example, a rectangle can be swept along a linear path to generate a rectangular prism. In computer graphics, this way of generating a 3d object is called **translational sweep** or **extrusion**. Other objects can be created rotating a surface around an axis. For example, rotating a rectangle around one of its edges produces a cylinder. This operation is known as **rotational sweep**.

Most packages include a set of ready-made 3d surface primitives, like cube, wedge, cylinder or sphere, which are internally made up of separate facets.

## 3D PRIMITIVES:EXAMPLES

## Autocad

Different sorts of SWEEPING operations are included in AutoCAD. The oldest implementation is the command CHANGE PROPERTIES, with the option 'thickness'. 'Thickness', in AutoCAD's language, is the dimension of the extrusion path, and thickness is a property of a 2d object (also a point might have thickness). For example, to generate a rectangular prism it is necessary to give a value to the 'thickness' of a closed PLINE. The object generated this way will be an open solid, with no surfaces in the faces that are perpendicular to the extrusion vector.

The reasons for this rather awkward form of extrusion need to be found in the history of AutoCAD, in the time when the program made the transition from 2d to so-called 2.5d. (see also the command ELEVATION, in this regard).

In later versions, AutoCAD incorporated true 3d entities, like the 3DFACE. A 3DFACE is a surface that results from connecting 3 or 4 points which do not have to be necessarily coplanar.

AutoCAD commands used to generate polygon meshes and polyhedra are:

TABSURF, tabulated surface mesh. A surface is generated from a path curve and a direction vector.

REVSURF, to create a surface of revolution rotating a profile about an axis.

EDGESURF, to create a Coons surface path from four edges.

RULESURF, to create a surface mesh between two objects, for example, two lines.

The density of the meshes created by the previous commands is controlled by the variables SURFTAB1 and SURFTAB2.

Pre-defined surface objects, are available in the menu DRAW: SURFACES: 3DOBJECTS (alternatively, type 3D in the command window). These objects are internally built as individual faces (AutoCAD's 3DFACE). The command EXPLODE is used to decompose the 3dobject into individual faces.

