IV.1 Introduction

Geometric information is very important in a production because it intervenes throughout the life cycle of a product in addition to the required operation, constraints, and optimization criteria that are derived from market considerations, and which serve as an input for the design process (Figure I.1). The designer generates the detail, the specifications of the parts and the assemblies to be produced. These specifications are mainly geometric information about the objects, with non-geometric data such as the materials used, technical characteristics, ... etc. [2].

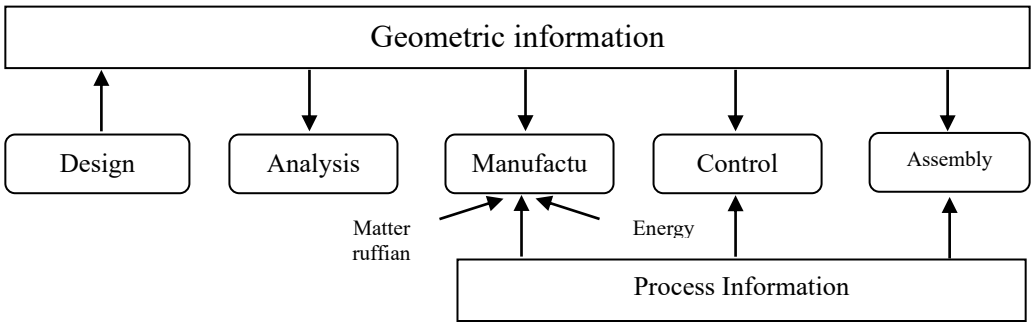

Figure I.1 [2]: Use of geometric information during the life cycle of a product

IV.2 3D Models (of Solids)

There are several types of 3D models that vary according to their uses and the data used. Nevertheless, as far as we are concerned, there are three main types of model [3]:

- "Geometric" models: for this type of model, we are interested in the geometric and dimensional properties of objects by exploiting topological information. They are mainly used in the fields of CAD and CAM. This type will be dealt with in detail in the next paragraph.

- "Vision" models: in a vision model, the data provided by 2D or 3D vision tools (3D point cloud, 2D views, contours,...) is used. among these models are the multi-view models, Delaunay triangulation, etc. etc. Among the fields of application of this type of model are medical imaging, as well as pattern recognition.

- "Deformable" models: this type of model is mainly used to simulate the behavior of deformable objects (super quadric, hyperquadric) and the interaction with their environment (physical models), and their tracking in space and time (snakes, adaptive mesh).

IV.2.1 Geometric models

Because these types of models are the most used to model mechanical parts, it would be interesting to see them in more detail below. According to their simplicity and performance, we divide geometric models into three categories: wireframe, surface, and volume [3].

IV.2.1.1 Wireframe models

The wireframe model of an object is a graph whose nodes are points on the object's surface (vertices or corners) and the features of the graph are the physical edges of the object. These representations do not contain information for surfaces and remain incomplete (Figure I.2)[3].

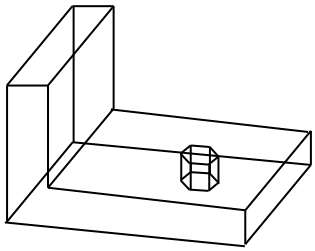

Figure IV.2: Construction of a wireframe model

Polyhedral wireframe modeling is widely used in computer vision because of its simplicity and as a good medium for topological and spatial information. For this type of wireframe model, the faces are flat polygons delimited by a list of edges delimited by corners [3].

Benefits:

1. simple
2. Fast viewing
3. requires minimal computing power

Disadvantages:

1. ambiguous (we do not distinguish between emptiness and fullness)
2. possibility of creating solids without any physical sense.
3. Difficulty in solving the problem of hidden parts.
4. It is impossible to calculate certain physical properties such as weight.

IV.2.1.2 Surface models

Surface modeling came to fill the gaps in wireframe modeling (Figure I.3) with this type of model, an object is defined by one or more more more or less complex surfaces that represent its envelope (its skin) [4]. These surfaces can be flat, which provides simplicity and speed of manipulation, as well as non-planar surfaces such as the NURBS surfaces widely used for CAD/CAM modelers and which give an exact presentation of the object. Calculating curve-surface or surface-surface intersections, for example, requires solving a very complex mathematical problem. A surface model is said to be valid when it defines an envelope that approaches the solid and forms a volume occupying a portion of the space.

The most widely used surface model is the Boundary Representation (BRep) model. It defines the object with surfaces and boundaries (boundary) that separate them, so it provides two types of information: geometric (coordinates of nodes, equations of curves and surfaces... etc.), and topological (description of the links and relationships between surfaces) [3].

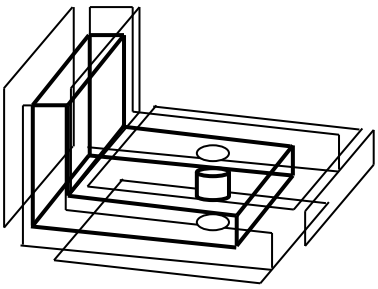

Figure IV.3: Construction of the Brep model.

Avantages:

1. ease of description, visualization and geometric transformations.
2. The faceted model makes it easy to perform complex operations such as calculating the volume of a solid, verifying the belonging of a point to the solid, etc.
3. it offers the possibility of geometric stress placement and assembly for CAD applications.

Disadvantages:

1. great difficulty in carrying out logical operations
2. difficulty of validation (the faces do not always constitute a volume)
3. It is necessary to store a large amount of information
4. great difficulty in going back during a design.

IV.2.1.3 Volume model

In a volume model, the volume of the object is directly modelled. There are two main categories of models: voxel-based models (elementary volume) and CSG (Constructive Solid Geometry) models.

IV.2.1.3.1 Voxel Models

In this type of model, the solid is represented by a list of voxels (volume element). Voxels are spatial cells occupied by the solid; They are usually fixed-size cubes distributed in a grid. In general, the solid is defined by the list of coordinates of the centers of the cells. The advantages are ease of validation, simplicity of access to a given point and spatial uniqueness assured. On

the other hand, it should be noted that there is no structure between the different parts of an object, that it is expensive in terms of memory and that consequently, it is not possible to represent very complex objects [3].

IV.2.1.3.2 Octrees

The main method of cell decomposition is the octree, which is a generalization of quadtrees. A quadtree is the representation of a 2D object based on the recursive subdivision of a square of the same size (quadrants). The octree is therefore an extension for encoding solids. A cubic region is recursively divided into 8 octants (cubic regions) (Figure I.4).

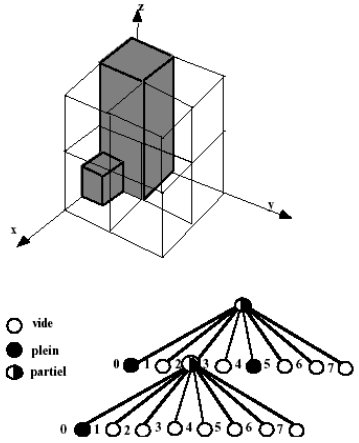

Figure IV.4 [4]: Modélisation par octrees

IV.2.1.3.3 Constructive Solid Geometry (CSG) model

In this model, we have a set of elementary volumes (parallelepipeds, spheres, cones, toruses,... etc.). The composition between these elements makes it possible to construct more complex objects (Figure IV.5). The CSG is based on the definition of geometry by an acyclic construction graph whose leaves are primitive (elementary) volumes and the nodes of Boolean composition operations (union, intersection,...).

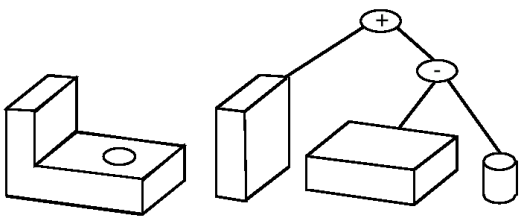

Figure IV.5 [4]: Construction of the CSG model

Avantages :

1. Ease of description (of the moving object and its trajectory),
2. Ease of storage,
3. Ease of geometric transformation,
4. Allows the creation of very realistic renderings.

Désavantages :

1. Lack of algorithmic tools for the calculation of geometric properties,
2. Does not allow for an explicit definition of the surface of the object,
3. Difficulty in implementing Boolean operators.

IV.4 Interchange Format

IV.4.1 format STL

It is a format used for rapid prototyping (stereolithography). It is usually obtained by triangulating an exact model using CAD software that provides us with a file in STL format. This file contains the vertices and the outward-facing normal for each triangle (Figure IV.13).

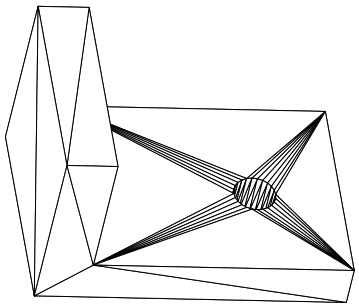

Figure IV.12 : STL triangulation of a part

The number of triangles and their distribution depend on the exact surface curvature and the permissible modelling error (Figure IV.12).

```
solid AutoCAD
   facet normal 9.9518473e-001 9.8017140e-002 1.4995834e-016
      outer loop
         vertex 1.4982954e+002 1.4375448e+002 4.0000000e+001
         vertex 1.4982954e+002 1.4375448e+002 0.0000000e+000
         vertex 1.4949841e+002 1.4711646e+002 0.0000000e+000
      endloop
   endfacet
   facet normal 9.9518473e-001 9.8017140e-002 -5.5716294e-016
      outer loop
         vertex 1.4982954e+002 1.4375448e+002 4.0000000e+001
         vertex 1.4949841e+002 1.4711646e+002 0.0000000e+000
         vertex 1.4949841e+002 1.4711646e+002 4.0000000e+001
      endloop
   endfacet
   ...
```

Figure IV.13 : An excerpt from an STL file.

IV.4.2 IGES format (. IGS):

This format, despite its limitations, is one of the most widespread for viewing or exporting 3D CAD models. It represents wireframe or surface models. If your model is solid, exporting to an IGES format will only save the outer "skin" of your solid. To recover a solid, you will then need to use a function of your modeler that allows the generation of a solid from its surface boundary. Most CAD modelers allow the import of IGES geometry.

IV.4.3 STEP format: exchanging technical data

STEP stands for the Esperanto of solid 3D CAD. It is becoming the standard for exchange between the major CAD platforms. However, its interpretation may vary from one publisher to another, which sometimes leads to errors or loss of information on the models. In addition, the solid geometry is retrieved as an uneditable block (the specification tree is not transmitted) but can be used as a basis for new functions. For assemblies, STEP encapsulates all the models, parts and products in a single file, which greatly facilitates exchanges. Manage all data relating to products, regardless of their origin, content or meaning, through all stages of its life cycle (specifications, design, manufacturing, quality control, sales, maintenance, etc.)