Chapter I

Geometric Modelling and Computer-Aided Design

ABSTRACT

One of the key activities in any product design process is to develop a geometric model of the product from the conceptual ideas, which can then be augmented with further engineering information pertaining to the application area. For example, the geometric model of a design may be developed to include material and manufacturing information that can later be used in computer-aided process planning and manufacturing (CAPP/CAM) activities. A geometric model is also a must for any engineering analysis, such as finite element analysis (FEA). In mathematical terms, geometric modelling is concerned with defining geometric objects using computational geometry, which is often, represented through computer software or rather a geometric modelling kernel. Geometry may be defined with the help of a wire-frame model, surface model, or solid model. Geometric modelling has now become an integral part of any computer-aided design (CAD) system. In this chapter, various geometric modelling approaches, such as wire-frame, surface, and solid modelling will be discussed. Basic computational geometric methods for defining simple entities such as curves, surfaces, and solids are given. Concepts of parametric, variational, history-based, and history-free CAD systems are explained. These topics are discussed in this opening chapter because (a) CAD was the very first computer-aided technologies developed and (b) its related techniques and methods have been pervasive in the other related subjects like computer-aided manufacturing. This chapter only discusses CAD systems from the application point of view; CAD data formats and data exchange issues are covered in the second chapter.
INTRODUCTION TO GEOMETRIC MODELLING

The geometric information about an object essentially includes types of surfaces, edges and their dimensions and tolerances. Prior to the availability of commercial CAD systems, this information was represented on blueprints by a draftsperson, hence in a two-dimensional (2D) form. This form of representation has three acute problems. First of all, it is hard to comprehend complex geometry through a 2D form of description. This is particularly true with assemblies that have many components, e.g. an engine assembly. Secondly, the design information in this form is difficult to be archived for a longer period of time and it is cumbersome to search for. Thirdly, it is considered unfit for the modern manufacturing industry in which data management is mostly in the electronic format. As manufacturing rapidly enters into the digital era, the emphasis is on paperless and total integration. That is, the means is being sought for the geometric information to be directly transferred from a CAD database to a CAPP/CAM database (sometimes bi-directional data flow is also required) to enable subsequent manufacture of the part. This way, product development and manufacturing lead time can be significantly shortened. In order to meet the above discussed needs, an accurate, efficient and effective representation of the complete information about a design becomes a prerequisite for many subsequent applications. The remaining of the chapter provides a detailed account of various geometric modelling approaches and the ways today’s CAD systems use these modelling approaches.

GEOMETRIC MODELLING APPROACHES

The development of geometric modelling is coupled with three departments of sciences and technologies. They are computer graphics techniques, three-dimensional (3D) geometric representation schemes and computer hardware advances. The research started in the 1960’s. The basic geometric modelling approaches used in today’s CAD/CAM systems are wire-frame, surface and solid modelling. In the following sections, a basic account of these approaches to geometric modelling is presented.

Wire-Frame Modelling

In the historical roadmap of geometric modelling, wire-frame is the first developed and is also the most basic method of geometric modelling techniques. The techniques were initially developed particularly for computer version of a 3D object. The basic entities in a wire-frame model may include points, lines, arcs and circles, conics, and other type of curves. Figure 1.1 shows the wire-frame representation of a part.

Wire-frame representation may be regarded as an extension into a third dimension of the techniques used for 2D drafting. The construction techniques used for the definition of wire-frame geometry are again broadly similar to those for 2D drafting. Therefore, the wire-frame scheme is relatively straightforward to use, and is the most economical of the 3D schemes in terms of computing time and memory requirements. This is why wire-frame was also well matched for the early models of computer hardware that was probably just capable enough to handle wire-frame representations. The scheme was found, and is till, particularly useful in certain applications involving visualisation of the motion of simple
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