1.0 Introduction

Shapes can be represented either intuitively or mathematically. The use of mathematics results in shape description becoming objective rather than subjective. Another advantage resulting from use of mathematical descriptions of shapes is that it facilitates the use of computers to process data and analyze information related to the description. Software for shape description was initially developed for numerical control (NC) machines in the 1950s. In the 1960s, it became possible to use computer control for basic and detailed design [Yama88]. This gave rise to a new paradigm in design wherein one could utilize the mathematical model stored in a computer instead of the conventional design based on drawings.

From such a beginning, geometric modeling or computer aided geometric design (CAGD) has evolved to a stage where it is widely used in engineering design and manufacture. The term geometric modeling is used to characterize the methods used in describing the geometry of an object. CAGD can be described more formally as dealing with approximation and representation of curves and surfaces using computers [Bohm84]. Over the years, various schemes have been developed with a view to achieve this abstraction. Ferguson is credited with introducing the idea of parametric curves and surface patches in the 1960s at Boeing. S. A. Coons introduced the coons patch in 1964. The Coons patch approach is based on the premise that a patch can be described in terms of four distinct boundary curves. These approaches proved too cumbersome to gain effective control over the geometry. Bézier introduced parametric curves and surfaces based on control points, which remedied this problem. Bézier curves and surfaces were well-behaved and suited to shape control. However, the problem of geometric continuity still remained unsolved. Gordon and Reisenfield introduced B-splines that eliminated the problem of geometric continuity as well [Yama88].

Since their introduction, B-splines have become the standard for representing geometry [Roge90]. This is particularly true for the aerospace, automotive and shipbuilding industries, which typically require free form surfaces to be modeled with a certain degree of precision. A technique known as geometric trimming is used to achieve this approximation to a free form surface. Rojas [Roja94] has described geometric trimming of C^2 B-spline surfaces in detail. His procedure makes use of approximations, error analysis, and means to visually manipulate the surfaces generated. Given below is a step by step procedure used by him:

- Create a B-spline surface to interpolate a given set of data points using an inversion procedure. He uses Fleming's modified constraint based algorithm [Flem92a] [Flem92b].
- Define a trimming curve in parametric space. Typically, this trimming curve results from the intersection of two surfaces.

- Create a new surface that matches the original surface as closely as possible minus the portion chopped off by the trimming curve.
- Implement an error measurement procedure that reflects the accuracy of the procedure.
- Visually display the results.

This method yields its best results when the trimming curve is perpendicular in parametric space. In fact more perpendicular the curve, better the results. This is due to the fact that only u-continuity constraints can be specified at the trimming curve without affecting the overall continuity of the remaining surface [Roja94]

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Figure (1.1) shows the wire frame model of an aircraft with the intersection curve for two of its surfaces visible. Since the trimming curve results from the intersection of two cubic surfaces, its degree is very high. The high degree of the curve means that floating points operations introduce significant numerical precision error. For this reason, the trimming curve is reparameterized and approximated by a number of cubic curves. Therefore, whenever a designer attempts to approximate existing high-order surface patch(es) by newly created low-order surface patch(es), error is introduced in the process. The designer needs to have some measure that tells him/her, how well the new patch matches the existing one.

The objective of this research is to develop tools that give the designer feedback on how well the new surface matches the existing one. Visual perception of the two surfaces rendered together is probably the most intuitive tool available to the designer. For two surface patches that are closely matched, it would ideally be very difficult to distinguish between them on screen. However, the size of the Z-buffer (typically 24-32 bits) severely limits the effectiveness of this type of analysis. Moreover, as with other sensory inputs, visual perception fails to quantify the error between two patches. The tools proposed herein provide quantitative feedback into the behavior of the new patch with respect to the original. This information can be analyzed and the new patch reparametrized or recreated to better approximate the existing surface. The designer can also automate the above procedure based on inputs gathered at various stages of the analysis.

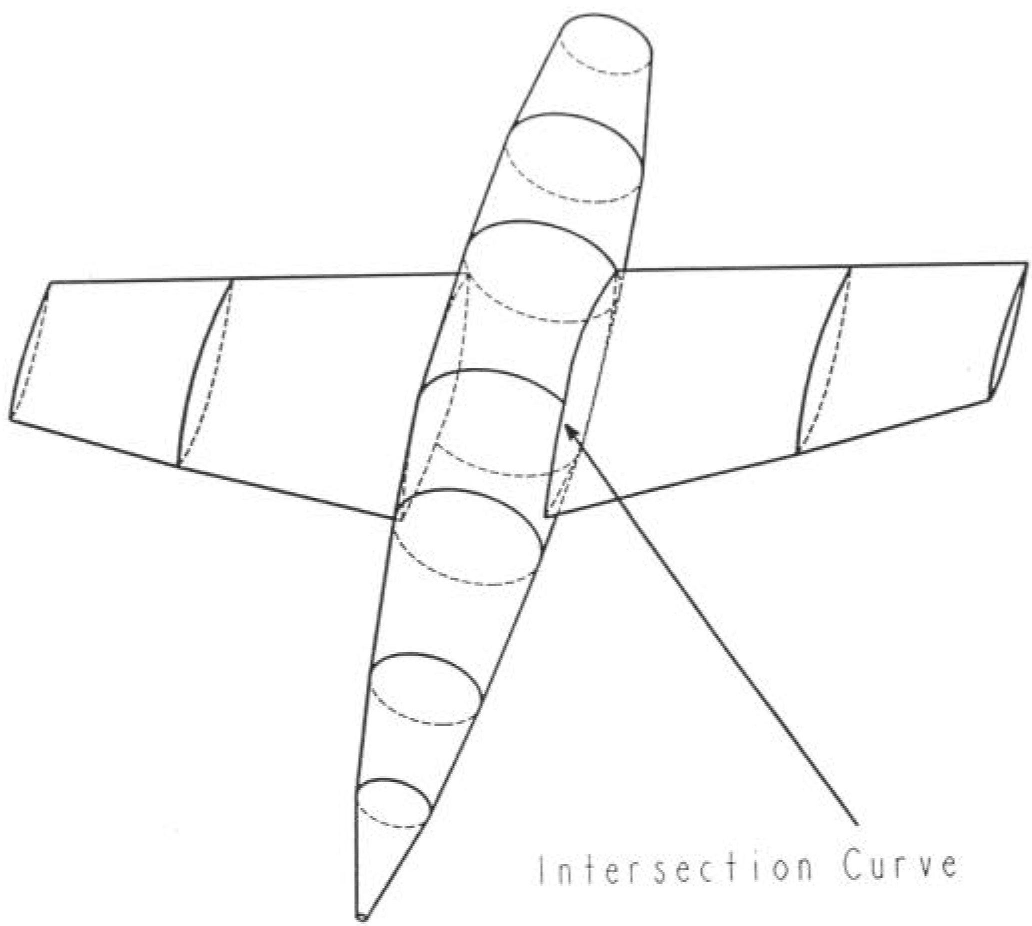

Figure 1.1: Wireframe model of an aircraft showing the trimming curve generated by two intersecting surfaces [Flem92a].