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A curve-fitting genetic algorithm for a styling application

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Abstract

Fitting curves in computer-aided geometric design is generally regarded as an optimisation problem. Depending on the application, the conditions to be satisfied can make the problem difficult to solve using classic methods, and for this reason, stochastic methods, such as genetic algorithms appear to be appropriate. This article considers a curve fitting problem, with the objective of generating shapes with specific curvature variations for use in the design of car bodies. To this end, a particular curve model was developed and implemented within a genetic algorithm. The main characteristics of this algorithm are described and its promising results are presented. The conclusion will show that this technique can be used as an alternative method in the design of car bodies.

Keywords: Genetic algorithm; Continuous optimisation; Curve fitting; Shape design; Monotonous curvature

1. Introduction

Freeform shapes are designed during in the engineering of an increasing number of products, including cars, mobile phones and just about any consumer goods whose shape has been specially designed with an eye to style. Fitting curves and/or surfaces to measured data in a reverse engineering process is a recurrent task in such design. For example, cars are designed from a clay model on which a collection of data points is measured (see Fig. 1). These points are filtered through a CAD software and, through a variety of techniques, transformed in a continuous representation. The aim of this paper is to describe an alternative method that can be implemented in CAD softwares and used for industrial applications.

The geometrical requirements in designing freeform shapes are frequently numerous, sometimes arduous, and more or less compatible with one another. The problem of data fitting, in terms of optimal design, is generally addressed through optimisation techniques [1,6,7]. However, some cases involve highly constrained non-linear

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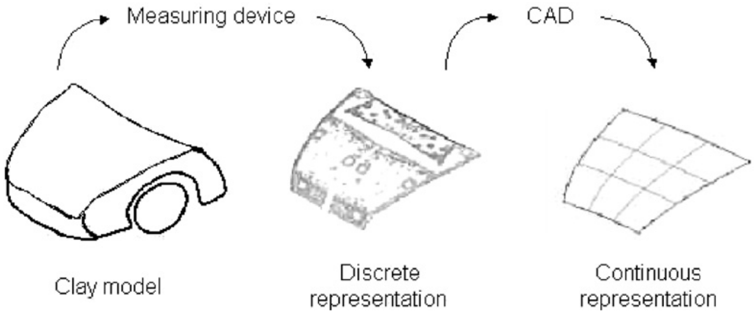

Fig. 1. A reverse engineering process.

problems that are cumbersome and difficult to solve using classic methods. Genetic algorithms would appear to be an appropriate alternative for solving this kind of problem, as has been shown in some of the existing studies in the field of curve fitting [8,13]. These algorithms, however, are normally dedicated to general design problems and do not allow the fine control required in the design of aesthetic shapes (for a general introduction of genetic algorithms in computer-aided design, please refer to [11]). The application we have developed and will present in this article concerns the fitting of constrained Bézier curves, which have extremely regular curvature variations. Our application aims to produce 2D section curves from which surfaces can be generated by using construction methods, such as blending or sweeping. Providing these curves are properly chosen according to the shape to be approximated, such a methodology can reliably insure the generation of accurate and visually pleasant shapes.

This reliable generation requires several quality characteristics, including

- an accurate approximation (where the distance between a measured point and its approximation remains less than a maximum error),
- a smooth curvature variation (for reflection lines),
- certain specific curve variations and
- an even control point distribution.

The rest of the paper is structured as follows. Section 2 introduces the section curve definition on which our method is based. Section 3 describes the main features of the problem itself and the characteristics of the genetic algorithm. An overview of the algorithm is given in Section 4, and the algorithm's results are reported in Section 5. Section 6 presents our conclusions.

2. Section curve definition

Shapes whose principal function is aesthetic must fulfill constraints that are primarily related to their curvature variation. Such features are traditionally expressed by visualizing the reflection lines; these lines which must be free of unexpected distortion and their location must vary smoothly according to the angle of the light reflection. Harmonious curvature variation on the section curves is necessary to obtain these characteristics. Curves with monotonically changing curvature are most often required for this purpose [3].

In previous work [10], Mineur defined a particular planar Bézier curve, called a typical curve with the aim of generating shapes with a monotone curvature variation. A typical curve possesses a control polygon with the same angle and the same length ratio between each adjacent polygon edge. Such properties provide the typical curves with an extremely smooth, monotone curvature variation, like the involutes of a circle, as well as other interesting mathematical properties. To cope with a high variety of shapes and to give to the typical curves much more versatility, Mineur has already proposed in [9], a G^2 (curvature) continuous piecewise curve model, in which each piece is a cubic typical curve (see Fig. 2). The definition of such