Multiple Aligned Characteristic Curves for Surface Fairing

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Abstract. Characteristic curves like isophotes, reflection lines and reflection circles are well–established concepts which have been used for automatic fairing of both parametric and piecewise linear surfaces. However, the result of the fairing strongly depends on the choice of a particular family of characteristic curves: isophotes or reflection lines may look perfect for a certain orientation of viewing and projection direction, but still have imperfections for other directions. Therefore, fairing methods are necessary which consider multiple families of characteristic curves. To achieve this, we first introduce a new way of controlling characteristic curves directly on the surface. Based on this, we introduce a fairing scheme which incorporates several families of characteristic curves simultaneously. We confirm effectiveness of our method for a number of test data sets.

1 Introduction

Visualization of characteristic curves provides a valuable and important tool for first–order surface interrogation (see [1] for a recent survey). Inspection of characteristic surface curves allows for rating and improving surface design as well as for intuitive detection of surface defects: on the one side, they simulate aesthetic appearance under certain lighting conditions and environment, while on the other hand continuity and smoothness of these curves visualize respective differential properties for surface derivatives.

Characteristic surface curves like reflection lines were originally (and still are) used for interrogation and design of physical models, and the concept is simulated for CAGD models in a virtual environment. Surprisingly these curves are mainly used for interrogation, and only few approaches exist which apply them for surface fairing and design [2,3,4].

Yet, the proposed methods that take advantage of characteristic curves in this setting all have in common that they only consider a single curve family, i.e., a main direction represented by these curves. This results in an optimized behavior of the curves for this single direction, but — as we will show in this paper — the single direction fairing does in general not also yield an optimized characteristic of all other curve directions at the same optimized location. In fact, our experiments indicate that the reverse is true.

Section 4 presents a new fairing scheme for triangulated surfaces that is capable of incorporating an arbitrary number of families *simultaneously*. Prior to that, for efficient use of this scheme in practice, in section 3 we develop intuitive methods for real–time curve control, i.e., determining parameters such that specific interpolation or alignment constraints on the surface are fulfilled. These methods allow for interactive and automatic curve specification.

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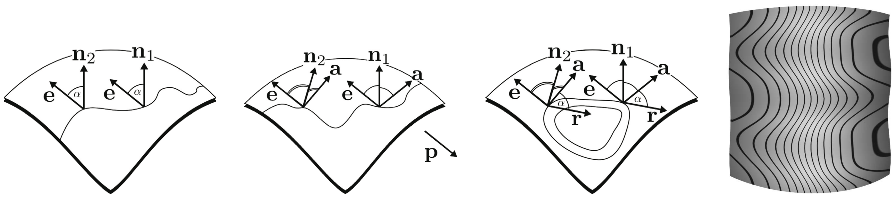

(**a**) Isophotes (**b**) Reflection lines (**c**) Reflection circles (**d**) Isophotes example

Fig. 1. Definitions of characteristic curves and example for family of isophotes on a wavy cylinder

1.1 Related Work

In this paper, we consider isophotes, reflection lines, and reflection circles. All these classes of characteristic curves are illumination curves since every curve originates from light–surface interaction [5].

Isophotes can be regarded as surface curves of constant incident light intensity which were extensively used to detect surface imperfections [6,5,1].

The reflection of a straight line on a surface is called reflection line. Just as isophotes, reflection lines possess special properties making them valuable for surface interrogation and surface fairing applications of parametric [2,3,7] and piecewise linear surfaces[4]. Recently, [4] applied reflection lines for fairing triangular meshes employing a screen–space surface parametrization. This work provides profound analysis of the arising numerical minimization and careful discretization of the emerging differential operators [8]. It is most similar yet different to this work.

Reflection circles arise from the reflections of concentric circles on a surface similar to reflection lines. Although reflection circles are the more general class of surface curves [9], they haven't been used as thorough as the other more specialized classes in surface–fairing applications. Still, recently [10] argue that a simplified version of reflection circles called circular highlight lines also performs well in surface–fairing applications.

There is vast literature on general surface denoising and fairing methods as well as fair surface design based on polygonal meshes, which we do not consider here but instead refer to a recent survey [11]. Similarly, we do not discuss alternative use of light lines such as surface reconstruction applications (see, e.g., [12]).

2 Characteristic Curves

We use definitions of characteristic curves — isophotes, reflection lines, and reflection circles (see figure 1) — which only depend on the normal directions of the surface and not on its position [9]. This means we assume that both, viewer and light sources (which are lines and circles), are located at infinity. This is a common simplification for various kinds of environment mapping. In the following, $\mathbf{e}$ denotes the normalized eye vector (viewing direction), and $\mathbf{n}(u, v)$ is the unit normal to the surface $\mathbf{x}(u, v)$.