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A sharpness dependent filter for mesh smoothing

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Abstract

In this paper, we propose a sharpness dependent filter design based on the fairing of surface normal, whereby the filtering algorithm automatically selects a filter. This may be a mean-filter, a min-filter, or a filter ranked between these two, depending on the local sharpness value and the sharpness dependent weighting function selected. To recover the original shape of a noisy model, the algorithm selects a mean-filter for flat regions and a min-filter for distinguished sharp regions. The selected sharpness dependent weighting function has a Gaussian, Laplacian, or El Fallah Ford form that approximately fits the sharpness distribution found in all tested noisy models. We use a sharpness factor in the weighting function to control the degree of feature preserving. The appropriate sharpness factor can be obtained by sharpness analysis based on the Bayesian classification. Our experiment results demonstrate that the proposed sharpness dependent filter is superior to other approaches for smoothing a polygon mesh, as well as for preserving its sharp features.

Keywords: Mesh fairing; Mesh processing; Mesh smoothing

1. Introduction

The goal of polygon mesh smoothing is to eliminate noise or uneven faces associated with a 3D polygon mesh model. In terms of signal processing, polygon mesh smoothing is regarded as a filter design problem. Recently, many smoothing methods that apply the concept of recursive fairing in filter design have been proposed. The fairing process adjusts the position of the polygon vertex so that uneven

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faces are gradually eliminated from the overall structure of the smoothed polygon mesh, while the fine structure of the model is preserved. Most methods regard smoothing as a problem of band-pass filter design. However, the drawback of frequency-based filtering techniques is that they blur the fine structure of the original model. When band-pass filtering techniques such as Gaussian or Laplacian operators are applied iteratively, a model not only becomes deformed, but also shrinks. Filter design, therefore, considers how to preserve a model's features, while preventing model deformity and shrinkage during the recursive process.

Many filter design methods formulate polygon mesh smoothing as a problem of energy minimization, in which energy can be defined by the curvature, gradient, vertex discrepancy, or other geometric attributes such as the angle between polygon faces (Alexa, 2002; Desbrun et al., 1999; Kobbelt et al., 1998; Weickert, 1997). For example, Desbrun et al. (1999) use the integral of the sum of the maximal and minimal principal curvatures as total energy, while Alexa (2002) uses the vertex discrepancy in a Wiener filter to obtain an optimal filter design. When dealing with a noisy model, minimization of global energy may cause too much local energy loss for some sharp areas and cause fine structures to become a little blurred. It is inevitable that the sharpness of two adjoining surfaces will be degraded if the curvature is used as energy for filtering. To solve this problem, Meyer et al. (2002) propose an anisotropic filter design using the two principal curvatures to classify vertex types according to local sharpness. However, most anisotropic filter designs detect the vertex type according to predefined rules using a preset threshold value, which sometimes generates an abnormal smoothing result.

In this paper we present a new approach to filter design for polygon mesh smoothing by selecting the polygon face normal from the distribution of its neighboring face normals. This formulation is simpler and more effective than other anisotropic filter designs. Basically, if a polygon face has no sharp edge on its boundary, then the face normal tends toward the mean of its neighboring face normals; otherwise, it tends toward the closest normal of its neighboring faces. Hence, the face normal governed by the sharpness dependent weighting function is a vector between the mean of neighboring face normals and the closest normal of neighboring faces. The sharpness dependent weighting function can be defined as the distribution of sharpness, which is the variance of the distribution of included angles between the normal angles of neighboring polygon faces.

The rest of this paper is organized as follows. In Section 2, we discuss related works and give some notations for filter design. Section 3 discusses the design of the mean-filter and ranking filter for a polygon mesh based on surface normal. Sections 4 and 5 detail our proposed method, based on the concept of sharpness dependent filter design. Section 6 provides our experiment results for the comparison of different feature preserving approaches. Finally, in Section 7, we present our conclusions.

2. Related works and notations

The filter design for polygon mesh smoothing considers a polyhedral surface $S = \{V, F\}$, where V and F are the sets of vertices and polygon faces, respectively; $v_i \in V$, $f_i \in F$ are the vertex element and face element, respectively; and Nv_i^v is the collection of neighboring vertices of vertex v_i. The Laplacian operator $L(V)$ for a parameterized surface is defined as follows:

$$L(V) = V_{uu} + V_{vv},$$