3차원 모델로 부터의 돌출선 감지 기술 연구

김수균*, 김석훈**

요약

컴퓨터 그래픽스 기술이 진화하면서, 비사실적 랜더링(NPR)과 같은 분야에서 폴리곤 메쉬에서의 돌출선 감지 기법은 매우 인기 있는 기술이 되고 있다. 돌출선은 폴리곤 데이터를 구성하고 있는 기하 정보를 통해 감지하게 된다. 본 논문에서는 3차원 모델을 잘 표현 할 수 있는 돌출선들의 집합을 선형적인 특징을 통해 감지하는 방법들에 대해 소개 할 것이다. 또한 본 논문에서는 현재 가장 많이 쓰이고 있는 인기 있는 돌출선 감지 기술의 특징을 분석하고 3차원 폴리곤 데이터에서 추출하는 방법에 대해 소개한다.

A Study on Crest Line Detection Techniques from 3D models

Soo-Kyun Kim*, Seok-Hun Kim**

ABSTRACT

With evolution of computer graphics, especially non-photorealistic rendering (NPR), detecting of feature from polygonal mesh became a very popular technique. Crest lines are some data detected from a polygonal mesh that contains a lot of information about the geometry of the mesh. Here we are interested in linear features, set of lines, that can best convey model's shape. The purpose of this paper is to overview the most popular types of features and methods to extract them from a 3D model represented by polygonal mesh data.

Key Words : Crest lines, crest detection, implict surface, NPR, 3D model

* 배재대학교 게임공학과(☒kimsk@pcu.ac.kr)
** (주)파라곤베이스
· 제1저자(First Author) : 김수균 · 교신저자(Correspondent Author) : 김석훈
· 접수일(2010년 5월 25일), 수정일(1차 : 2010년 6월 25일), 게재확정일(2010년 6월 29일)

Ⅰ. Introduction

In this section is aimed to define problem of crest line detection more clearly. The goal of works that will be presented in this paper is to extract linear features from an arbitrary 3D model, represented by triangle mesh data. Linear features or crest lines are curves on surfaces carrying - in a few strokes - visually most prominent characteristics [1]. That is having these feature lines we can convey much information about shape's geometry (Figure 1). Some works are aimed to convey all geometric information about the 3D model [2].

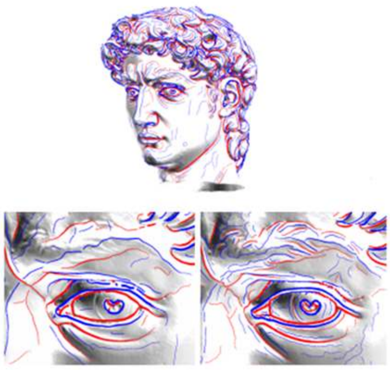


그림 1. 데이비드 모델. (파랑색) 리지와 (붉은색) 리지 선들 [3]
Figure 1. David model. (blue) ridges and (red) valley lines [3]

In this paper we can show existing methods in object-space approaches. we will concentrate on method descriptions, and we will provide with comparison of the methods.

Next section will provide with data representation description. Later we provide description of 5 methods, This method is based on object space approach.

Ⅱ. Data Representation

This paper considers only crests detection from polygonal mesh data, to be more precise, triangle mesh data. In 3D computer graphics any object is approximated with a set of connected triangles. Triangle has three points, which is a minimal requirement for an arbitrary plane presentation, and graphics hardware is specialized to process triangle data. These facts make triangle good choice for surface approximation (Figure 2).

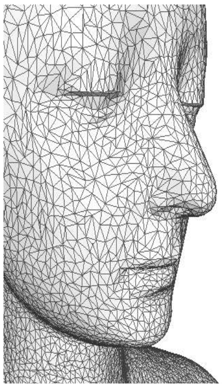


그림 2. 3차원 이폴리타 스포르차 모델
Figure 2. 3D model of Ippolita Sforza bust by Francesco Laurana scanned by Visual Computing Lab of the ISTI - CNR

Another popular approach used for 3D representation is a point cloud. Usually scanned 3d models are stored as the point set. In fact, 3D points are the most simple and fundamental geometry-defining entities [4]. But due to complexity of processing and visualization they are rarely used in interactive computer graphics applications, such as 3D games and computer animations.

III. Object Space Approach

In this section we present methods that process discrete 3D polygonal mesh data. Since mesh data has only C^0 continuity, it is impossible to directly estimate curvature. For this purpose standard technique introduced in[5] is used.

Lines along ridges and valleys are formed by local extrema of surface curvature along one of the principal curvature directions [3, 6, 7, 8] and might be considered a generalization of sharp creases to smooth surfaces.

3.1 Notation

In order to understand the process of feature extraction, we provide some differential geometry background in this section. Let S be a sufficiently smooth surface and $q \in S$ be a point on that surface.

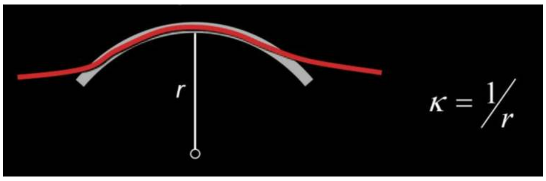


그림 3. 곡선의 곡률 [5]
Figure 3. Curvature of a curve [5]

Normal : Normal vector n at q is a unit vector that is perpendicular to the surface. Also normal vector is a first-order differential quantity of the surface.

Curvature : The second-order differential quantity of the surface is a curvature. Intuitively, curvature is an amount how much surface is bend, or how the normal changes from point to point on a surface. For a curve, curvature is a reciprocal of radius of circle that best approximates it locally (Figure 3).

Normal curvature : Normal curvature is a curvature of a curve obtained by intersecting the surface with the plane that contains q and the surface normal vector **n** at point q. For a smooth surface, normal curvature varies with the direction, and ranges between the principal curvatures $k_1(p)$ and $k_2(p)$.

3.2 Iso-Surface Approach

This paper proposed a general purpose tool designed to detect characteristic lines from 3D image data. Marching Lines is inspired from the Marching Cubes Technique which is used to extract iso-surfaces out of 3D images (Figure 4).

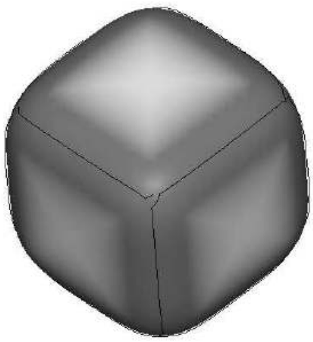


그림 4. 추출된 마칭 선들 [7]
Figure 4. Extracted Marching Lines [7]

The Marching Lines extracts with sub-pixel accuracy the 3D lines corresponding to the intersection of two iso-surfaces coming from two different 3D images.

3.3 Multi-Scale Approach

This approach presented a line-type features on point-sampled geometry(Figure 5).

They controlled input data such as an

unstructured point set, this method first applies principal component analysis on local neighborhoods to classify points according to the likelihood that they belong to a feature. Using semi-automatic thresholding, feature lines are computed a minimum spanning graph as an initial approximation.

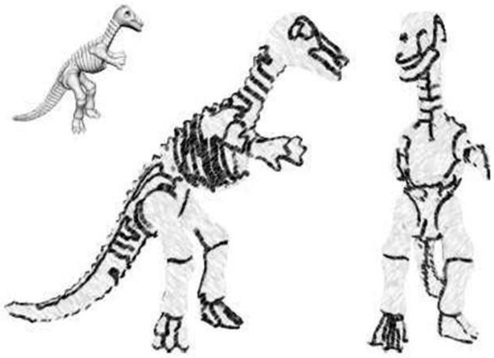


그림 5. 공룡 모델 [8]
Figure 5. Dinosaur model [8]

But this method required the user to specify a few thresholding parameters.

3.4 Finite-Differences Approach

Rusinkiewicz et al. [5] used finite-differences approach for estimating curvature (Figure 6). The computation can be considered as extension of common method for estimating per-vertex normals - compute curvature tensor for each face of mesh and Average face curvature tensors at touching vertices.

This algorithm presented efficient in time and space, robust method for estimating curvature on triangle meshes. Also the method shows better results than existing techniques, even with irregular tessellation and noises.

그림 6. [5]를 이용한 불규칙적인 테셀레이션된 모델에서의 계산된 곡률들의 가시화
Figure 6. Color-coded visualization of computed curvatures on irregularly-tessellated models using [5]

3.5 Implicit Surface Fitting Approach

Ohtake et al. [3] proposed a simple and effective method for detecting view- and scale-independent ridge-valley lines defined via first- and second-order curvature derivatives on shape approximated by dense triangle meshes (Figure 7). In this paper, ridge and valley lines or surface creases defined via extrema of the principal curvatures along their corresponding principal directions. This motivation is based upon the following analogy with edges of grey-scale images in image processing.

Since triangle mesh is discrete, not implicit, data it is impossible to estimate curvature derivative directly from the mesh. The input triangle mesh data is first approximated by implicit surface, then mesh vertices is projected on the surface. The curvature tensor and curvature derivatives at a mesh vertex are estimated by those at the corresponding surface point.

In this work, compactly supported radial basis function [9] was employed for the surface approximation. Specifically, a slight modification of the fast and easy to implement method developed in

[2], which can be used either for approximation or interpolation.

그림 7. 막스 플랑크 모델에서의 리지 (파랑색)과 밸리(붉은색) 선
Figure 7. Ridge (blue) and valley (red) lines from Maxplanck model [3].

3.6 Fast Computation Approach

Yoshizawa et al. [10] presented a fast method for detecting salient curvature extrema on surfaces approximated by dense triangle meshes (Figure 8).

This method compute the extremalities and the principal curvature directions at each vertex of the mesh in [10] a local cubic polynomial least square fitting combined with a simple mesh smoothing technique is used.

그림 8. 특징 선을 가지는 패라인 모델 (왼쪽)과 특징선과 윤곽선만 포함하는 모습(왼쪽)
Figure 8. Feline model with feature lines (left) and consisting of feature lines and a contour line only (right)

Ⅳ. Conclusion

We describe 5 different crest detection algorithms. First method presents a technique for computation of normal, curvature and normal curvature. Iso-surface method extracted crest lines from medical data. Third technique proposed to detect crest lines from point clouds. Others presented extracted feature lines from polygonal meshes using curvature and their derivatives.

Detected linear features can give us a lot of information about the shape of the model. This crest features are view-independent lines that can be successfully used for shape reconstruction. Because of view-independent nature, these lines look too blocky, and cannot be applied for artistic lines extraction.

Acknowledgement

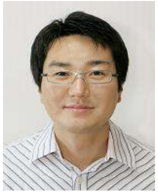
"본 논문은 2010년도 정부(교육과학기술부)의 재원으로 한국연구재단의 지원을 받아 수행된 기초연구사업임(No.2010-0015563)"

Reference

[1] Hildebrandt 2005 – Hildebrandt, K., Polthier, K., Wardetzky, M. 2005. *Smooth feature lines on surface meshes*. In 3rdEurographicsSymp.onGeom.Proc.,85 – 90.

[2] Ohtake 2003 - Ohtake Y., Belyaev A. G., Seidel H.-P. 2003. *A Multi-scale Approach to 3D Scattered Data Interpolation with Compactly Supported Basis Functions*, Proceedings of

the Shape Modeling International 2003, p.153, May 12-15.
[3] Ohtake 2004 – Ohtake Y., Belyaev A. G., Seidel H.-P. 2004. *Ridge-valley lines on meshes via implicit surface fitting*. Proc. Of ACM SIGGRAPH (2004), 609 – 612.
[4] Sainz2004 – Sainz M., Pajarola R. 2004. *Point-based rendering techniques*. Computer & Graphics 28.6, 869-879.
[5] Rusinkiewicz 2004 – Rusinkiewicz, S. 2004. *Estimating Curvatures and Their Derivatives on Triangle Meshes. In Symposium on 3D Data Processing*, Visualization, and Transmission.
[6] INTERRANTE V., FUCHS H., PIZER S.: *Enhancing transparent skin surfaces with ridge and valley lines*. Proceedings of IEEE Visualization (1995), 52 – -59.
[7] THIRION, J.-P., AND GOURDON, A. 1996. *The 3d marching lines algorithm*. Graphical Models and Image Processing 58, 6.
[8] PAULY, M., KEISER, R., AND GROSS, M. 2003. *Multi-scale feature extraction on point-sampled surfaces*. Computer Graphics Forum 22, 3 (Sept.), 281 – -290.
[9] Wendland1995 – Wendland H. 1995. *Piecewise polynomial, positive definite and compactly supported radial functions of minimal degree*, Adv. In Comp. Math. 4, 389-396.
[10] YOSHIZAWA S., BELYAEV A. G., SEIDEL H.-P.: *Fast and robust detection of crest lines on meshes*. Proc. of ACM Symposium on Solid and Physical Modeling (2005).



김수균(Soo-Kyun Kim)

2006년 고려대학교 컴퓨터학과
(이학박사)
2006.3 ~2008.2 삼성전자 통신연구소
책임연구원

2008년~현재 배재대학교 게임공학과 조교수
※ 관심분야 : 기하모델링, 게임그래픽, 실감미디어

김석훈(Seok-Hun Kim)

2003년 한남대학교 컴퓨터공학과
(공학석사)
2006년 한남대학교 컴퓨터공학과
(공학박사)

2007년~현재 (주)파라곤베이스 기술이사
※ 관심분야 : 웹 DB, 네트워크, VoIP, 모바일컴퓨팅