Surface Curvature Extraction for 3D Image Analysis or Surface Rendering

John Rugis and Reinhard Klette

CITR, Computer Vision Unit, Computer Science Department
The University of Auckland, Auckland, New Zealand.

Abstract

We consider dense discrete surface data as obtained via a high-resolution laser range finder, structured lighting, or given by triangulated surface meshes. We allow noise to some degree. The task is to estimate surface curvature, possibly with subsequent noise filtering, and also ensuring scale invariance if desired. Resulting curvature maps can be used for image analysis or surface rendering purposes.)

Keywords: Surface curvature, curvature maps, scale invariance, digital Michelangelo project.

The definition of curvature of continuous or discrete surfaces uses normal curvatures [2]; let κ_1 and κ_2 be the minimum and maximum normal curvature, respectively. Estimations of the mean curvature $(\kappa_1 + \kappa_2)/2$ (e.g., applying the method proposed in [1]) allow calculations of curvature maps which represent surface geometry accurately [4].

However, neither mean curvature nor Gaussian curvature $\kappa_1\kappa_2$ or curvedness $\sqrt{(\kappa_1^2 + \kappa_2^2)/2}$ are scale invariant. [5] proposed a 2D scale invariant curvature measure R based on $\kappa_3 = |\kappa_1|/|\kappa_2|$, with $\kappa_3 = 0$ if $\kappa_2 = 0$, defining a *similarity curvature space*.

Curvature estimation results may be enhanced by applying a purpose-designed 2.5D Gauss filter to calculated curvature estimates.

Theoretical and applied results of this project are illustrated for basic geometric shapes (such as a sphere, ellipsoid, cylinder, or torus) or very-high resolution surface scans of the digital Michelangelo project [3]. (The hexagonal scan pattern in this project is mapped into a slightly squashed array of smaller dots.) Accurate surface analysis of the David statue revealed smallest features on the David statue (see Figure 1) of a depth of only fractions of a millimeter (e.g., also marks of Michelangelo's chisel, or rarely visible engravings)

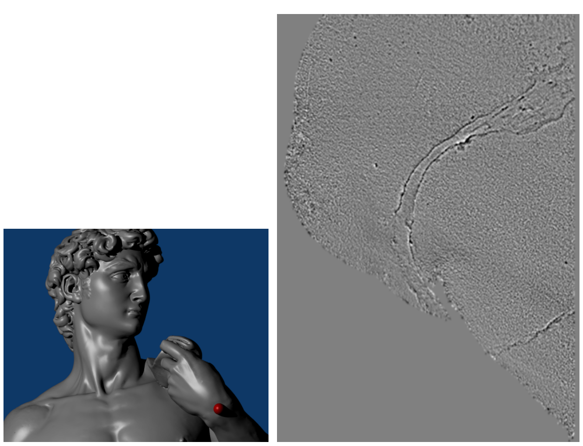

Figure 1: An area at the wrist of Davis (left, see marker), and its high-resolution curvature map (right).

Classified details can be used as registration markers for range scan data. Histogram templates are used to search through filtered and segmented curvature data for local surface features. For example, a histogram template is specified for identifying pit-like surface defects with radial symmetry. Feature maps are illustrated by an analysis of the face of David.

References

[1] L. Alboul and R. van Damme. Polyhedral metrics in surface reconstruction: tight triangulations. University of Twente, Dep. of Applied Mathematics, Technical Report, 1995.

[2] R. Klette and A. Rosenfeld. *Digital Geometry: Geometric Methods for Digital Picture Analysis.* Morgan Kaufmann, San Francisco, 2004.

[3] M. Levoy et al. The digital Michelangelo project: 3D scanning of large statues. In Proc. *Computer Graphics Interactive Techniques*, pages 131-144, 2000.

[4] J. Rugis. Projecting surface curvature maps. In Proc. *SIGGRAPH*, article no. 169, 2006.

[5] J. Rugis and R. Klette. A scale invariant surface curvature estimator. In Proc. *PSIVT*, pages 138–147, 2006.