Adaptive quantizations of triangle meshes

Ioannis Ivrissimtzis, Ying Yang and Norbert Peyerhimoff
Durham University

GPF 11-178 - Geometric Modelling meeting
Seoul, 2011

Durham University

Research themes

Statistical methods in surface reconstruction:

- Overfitting control
- Noise estimation - denoising
- Bootstrap methods
- Self-organising maps

Durham University

Research themes

Mesh watermarking and steganography

Subdivision curves and surfaces

- Geometry driven subdivision
- Subdivision surface artifacts

Durham University

Overview

- Quantized triangle meshes
- Computation of optimal quantizations
- Validation
- Applications

Motivation

Grayscale images are commonly encoded with **8** bits per pixel.

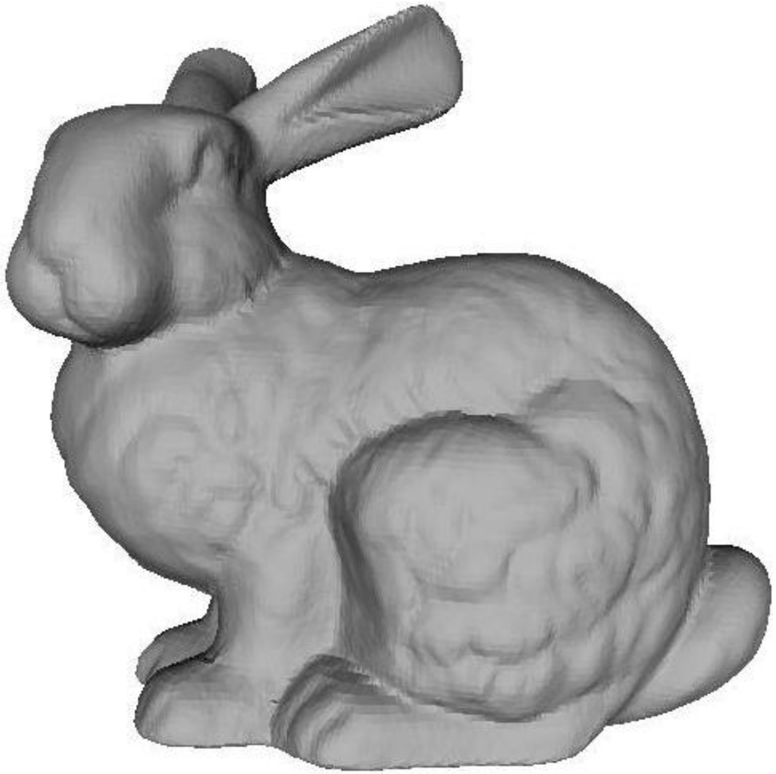
Durham University

Motivation

RGB colour images are usually encoded with **8** bits per pixel per colour band (e.g., RGB bands).

Durham University

Motivation



There is no widely accepted strategy to compute the appropriate quantization level of vertices of 3D models.

Durham University

Motivation

7 bits/vertex

Durham University

Aim

High Level: Model with a lot of redundancy

Low Level: Significant loss of geometric information

Develop algorithms for automatically determining appropriate levels of quantization for 3D triangle models.

Durham University

Context

The problem of choosing quantization level is ubiquitous but it is rarely the subject of systematic study.

Example:

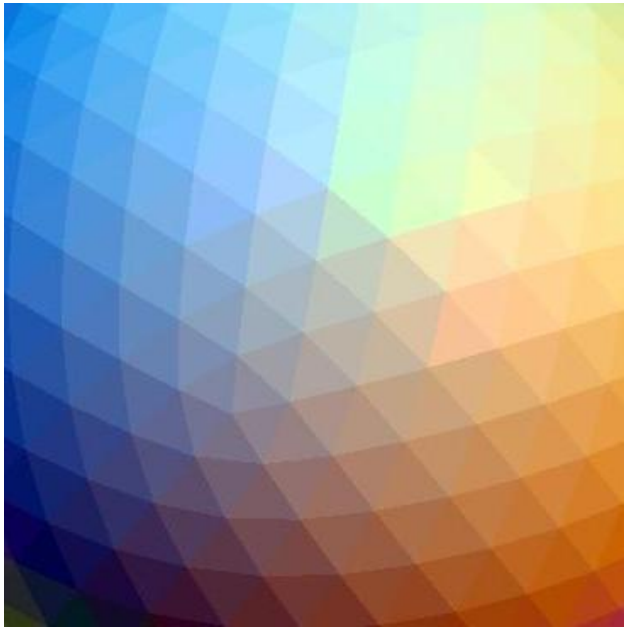
- Bus timetables are quantized by the minute
- Airport timetables are quantized in 5 minute intervals
- TV programs may be quantized in 15 minute intervals

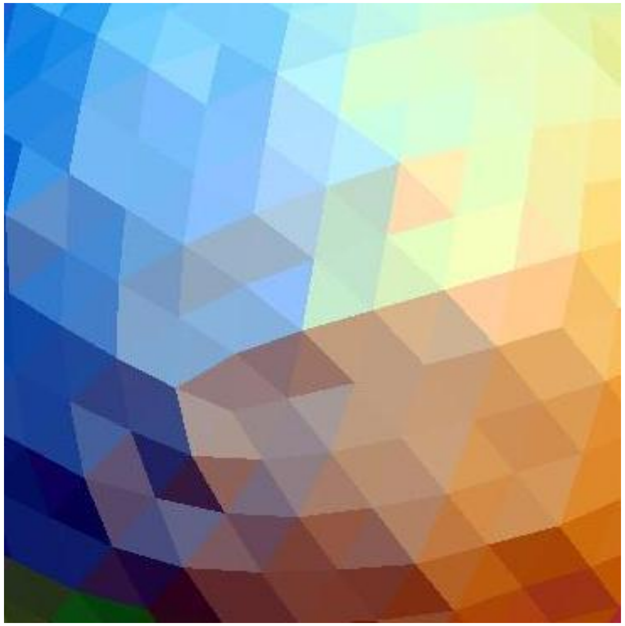
The optimal quantization level may depend more on the context of use and less on intrinsic properties of the data.

Durham University

Context

We are interested in visualization applications. The quality of the renderings depends on the quality of the normals.





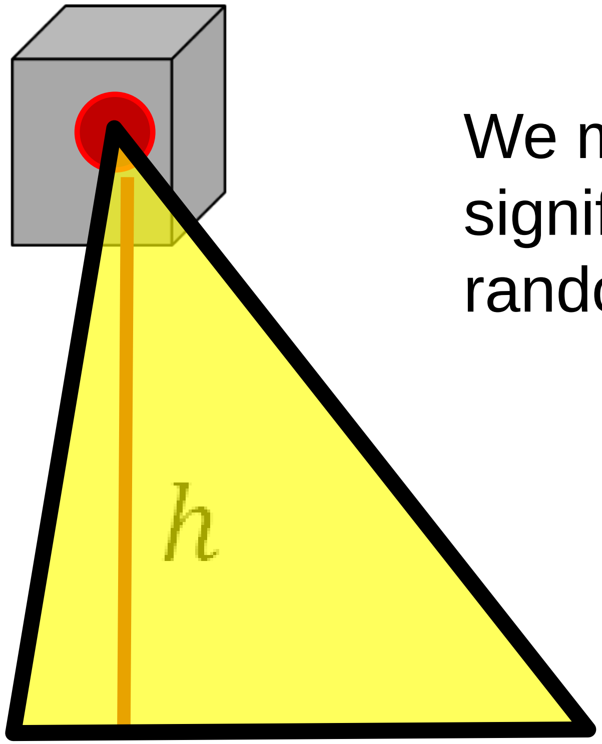
What is the effect of vertex quantization on face normals?

Overview

- Quantized triangle meshes
- Computation of optimal quantizations
- Validation
- Applications

Durham University

Randomize LSB of a single vertex



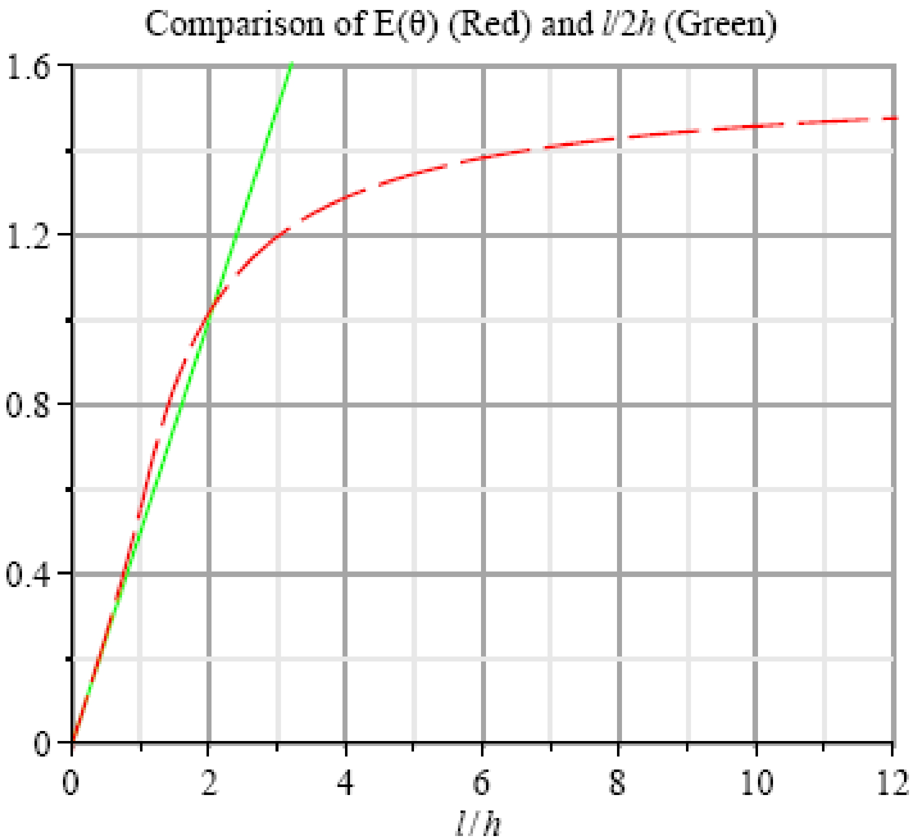
We model the randomization of the least significant bits as the addition of uniform random noise with cubic support.

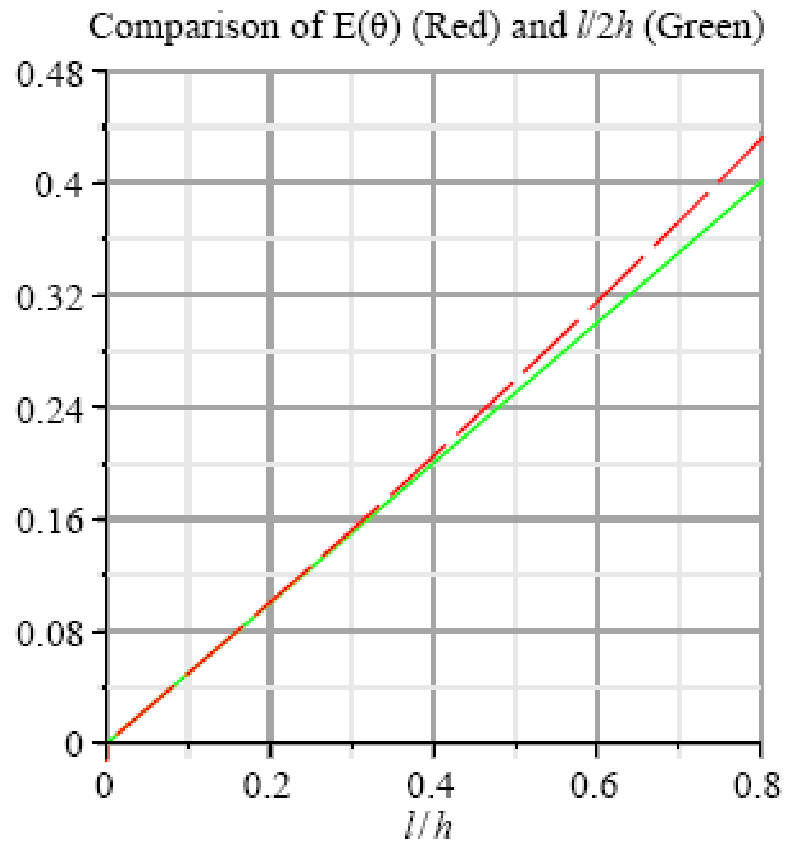
$$\mathrm{E}(\theta) = \frac{1}{2l^2}\int_{-l}^{l}\int_{0}^{l}\theta \; dz \; dy$$

$$\theta = \arccos((h+y)/(\sqrt{(h+y)^2+z^2}))$$

Durham University

Randomize LSB of a single vertex

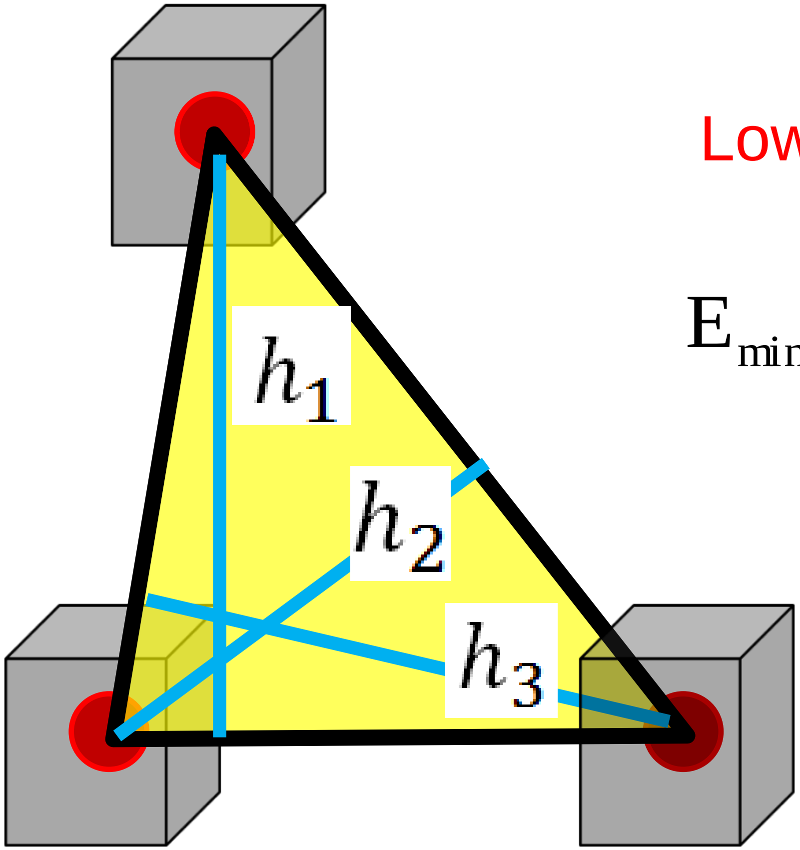




Linear relationship between ( ) and 1/h for small .

Durham University

Randomize LSB of three vertices

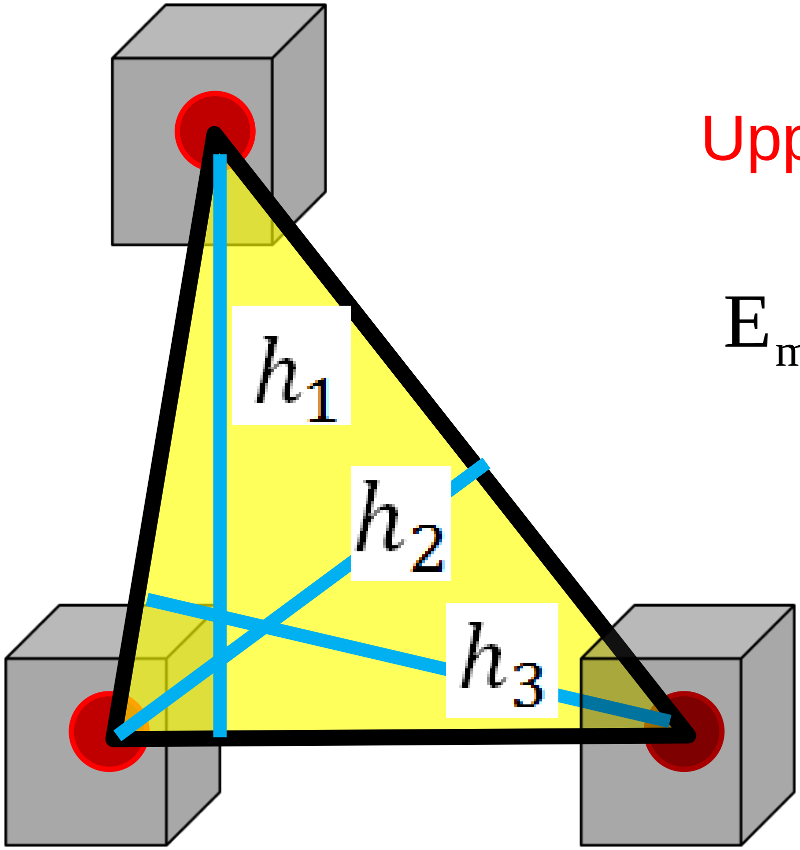


Lower bound:

$$E_{min}(\theta) = \max\{E(\theta_1), E(\theta_2), E(\theta_3)\}$$

Durham University

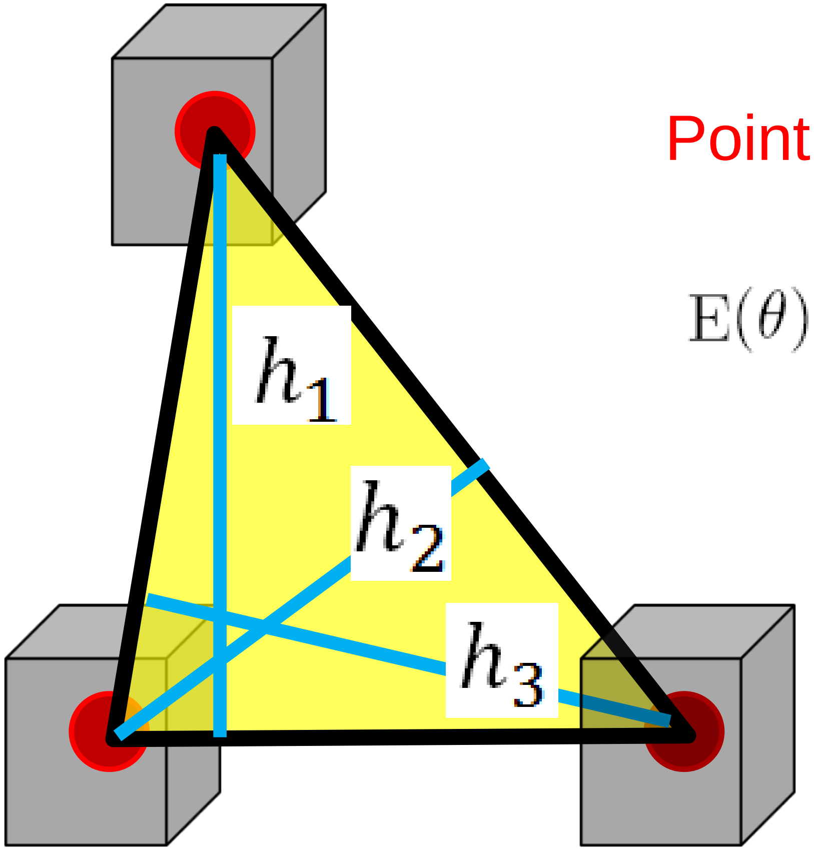
Randomize LSB of three vertices



Upper bound:

$$E_{max}(\theta) = 2E_{max}(\theta)$$

Randomize LSB of three vertices



Point estimation:

$$\mathrm{E}(\theta) = \eta \cdot (\mathrm{E}(\theta_1) + \mathrm{E}(\theta_2) + \mathrm{E}(\theta_3))$$
$$= \eta \cdot l \cdot (\frac{1}{2h_1} + \frac{1}{2h_2} + \frac{1}{2h_3}) = \frac{\eta \cdot l}{2\rho}$$

- ρ incircle radius
- $\lambda = 0.608$

Randomize LSB in whole mesh

Normal degradation for 3D model

$$\mathrm{E}_{mesh}(\theta) = \frac{\sum_{j=1}^{M} \mathrm{E}_j(\theta)}{M}$$

Quantization level computation

$$i = \arg\max_{i \in \mathbb{Z}} \{ i \mid \mathrm{E}_{mesh}(\theta) \leq \epsilon \}$$

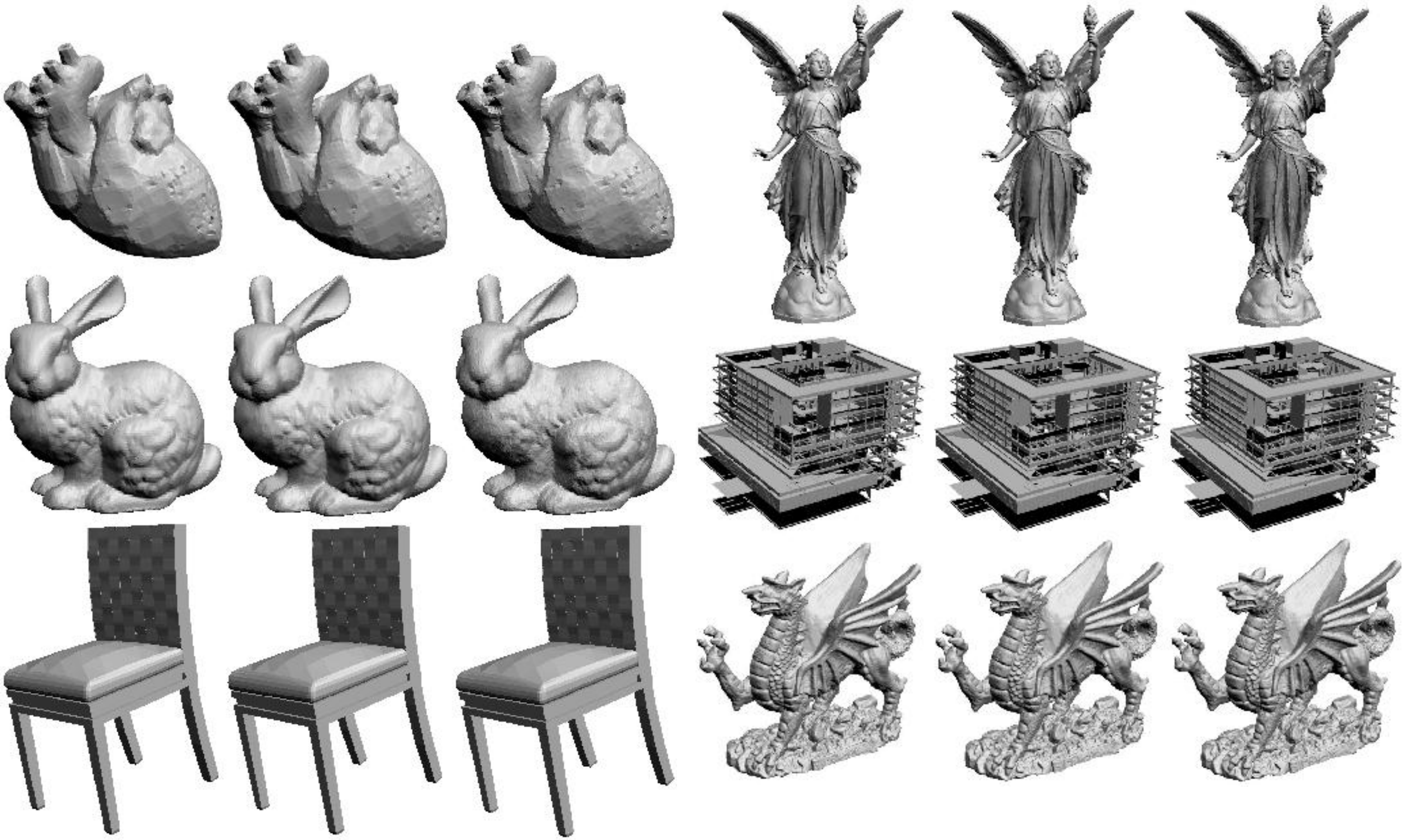
Durham University

Overview

- Quantized triangle meshes
- Computation of optimal quantizations
- Validation
- Applications

Durham University

Validation



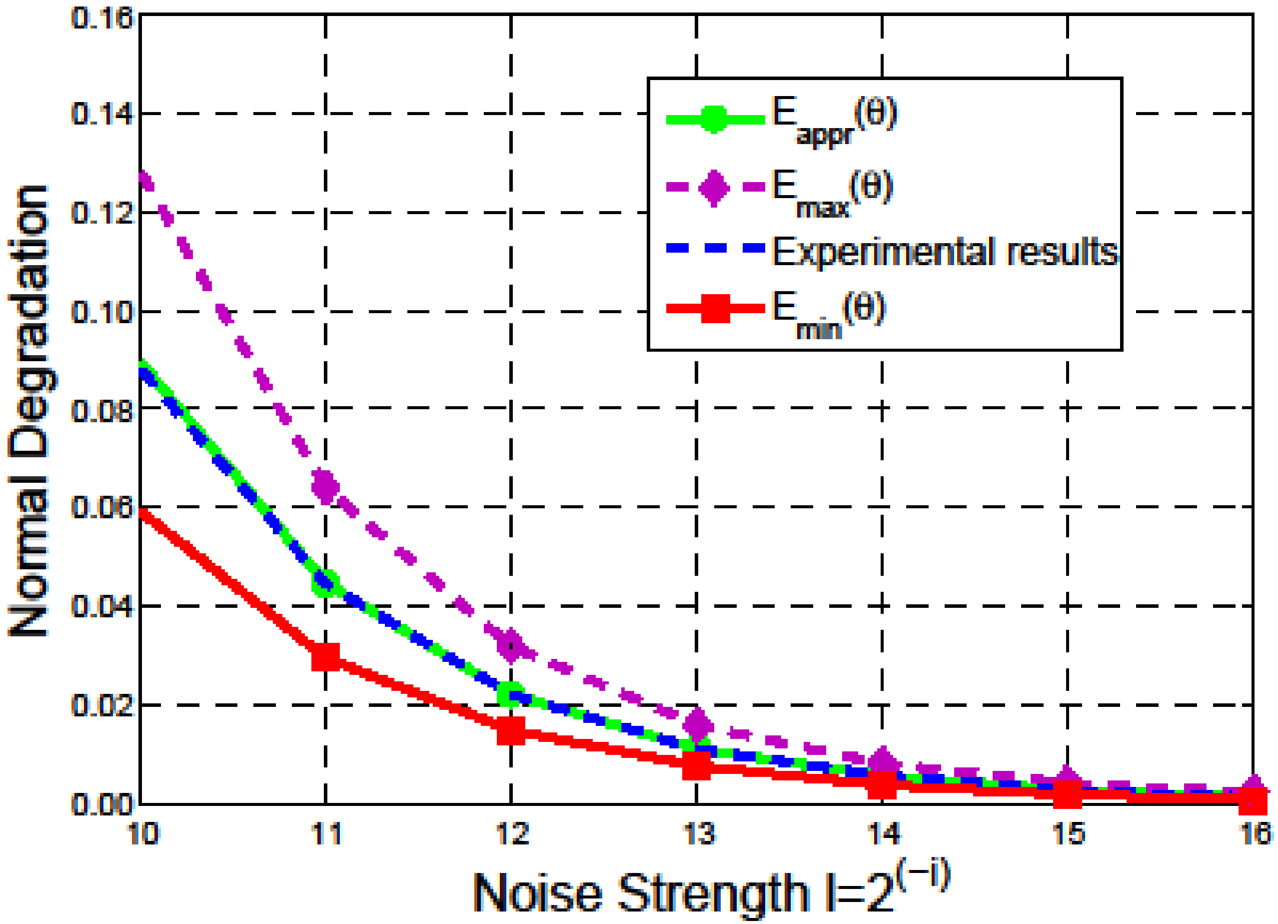
ε = 0.1°, 1°, 10°

Validation

	#Tri	$E_{min}(\theta)$			$E_{appr}(\theta)$			$E_{max}(\theta)$		
Heart	37690	16	12	9	16	13	10	17	13	10
Bunny	69666	17	13	10	17	14	10	18	14	11
Chair	6664	18	15	11	18	15	12	19	16	12
Lucy	525814	19	15	12	19	16	12	20	16	13
MPII Geometry	70761	21	18	15	22	18	15	22	19	16
Welsh Dragon	2210635	20	16	13	20	17	14	21	18	14

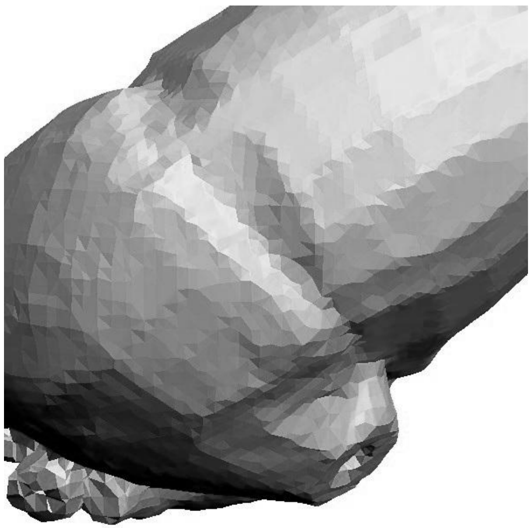
Durham University

Validation – Heart model

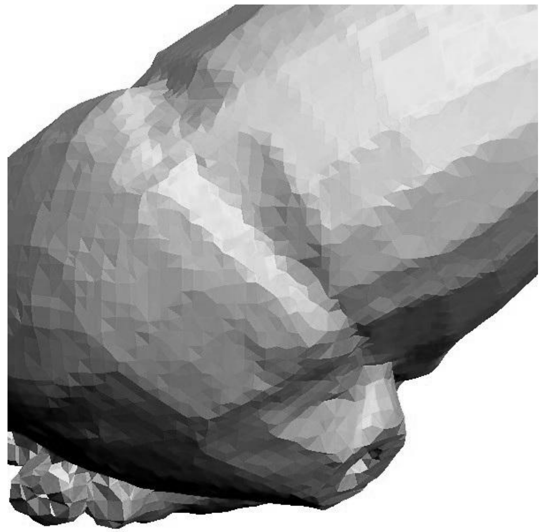


Durham University

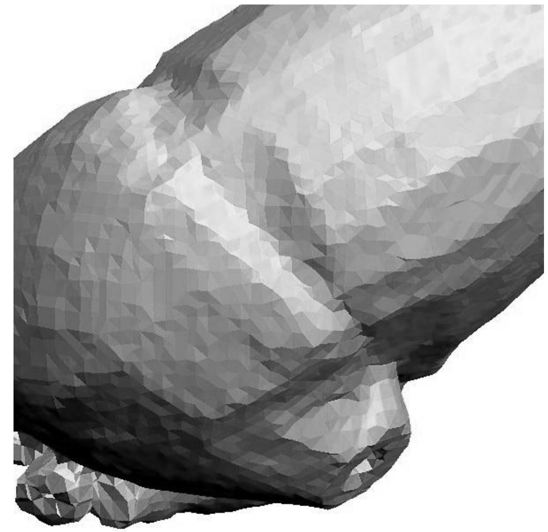
Validation – Heart model



ε = 0.1°



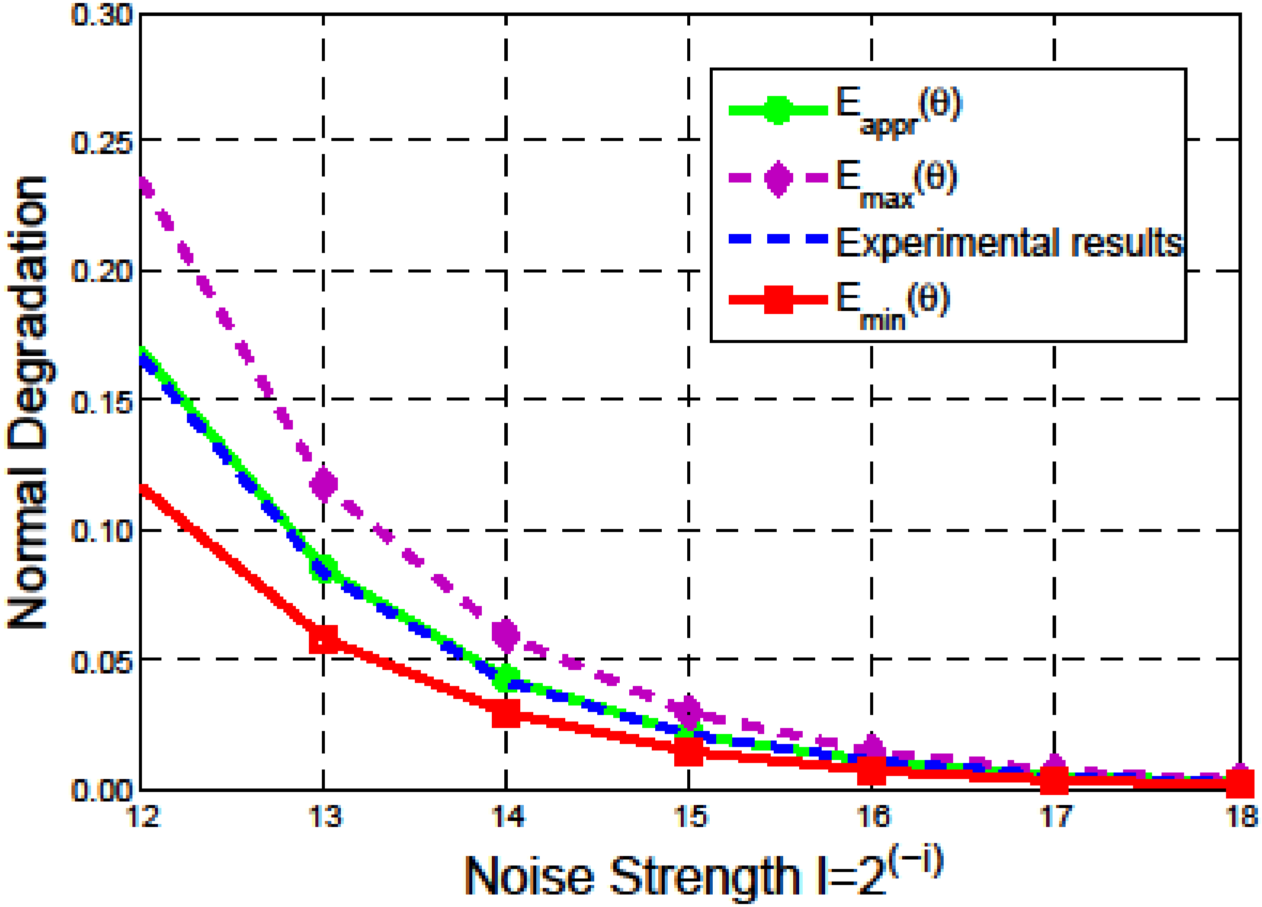
ε = 1°



ε = 10°

Durham University

Validation – Lucy model



Durham University

Validation – Lucy model

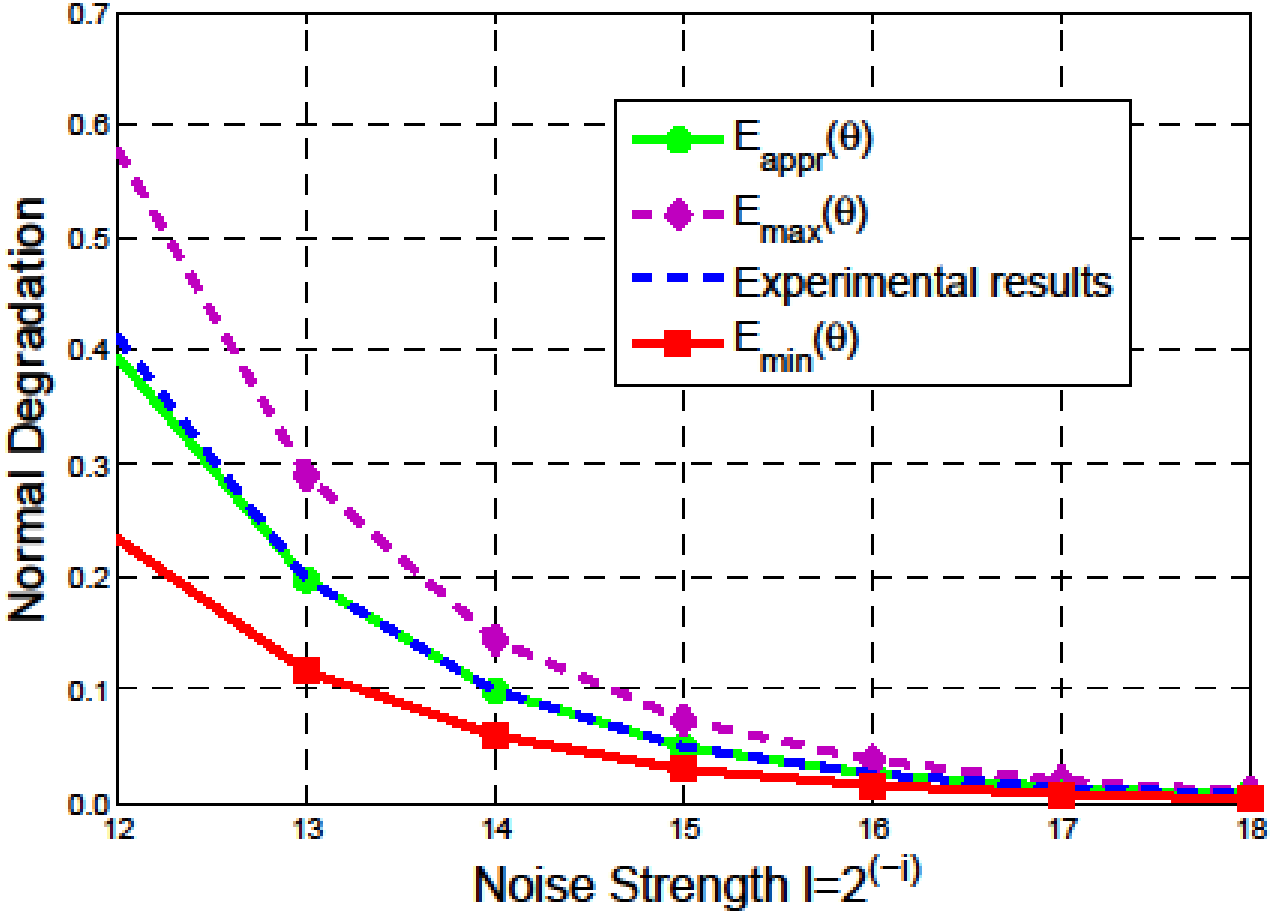
ε = 0.1°

ε = 1°

ε = 10°

Durham University

Validation – Welsh dragon

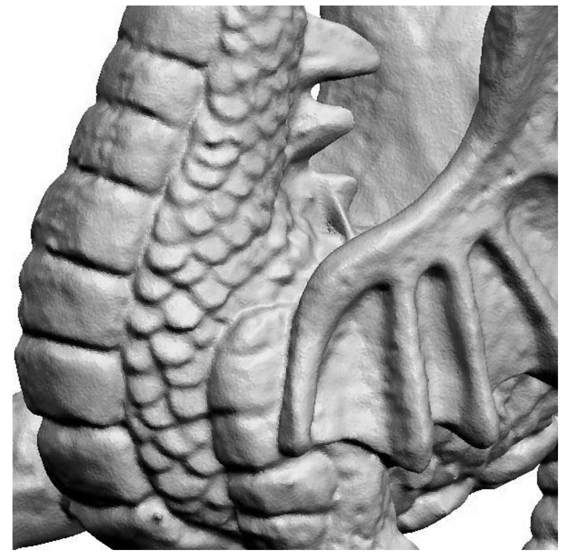


Durham University

Validation – Welsh dragon

ε = 0.1°

ε = 1°



ε = 10°

Durham University

Overview

- Quantized triangle meshes
- Computation of optimal quantizations
- Validation
- Applications

Durham
University

Adaptive quantization

Use various quantization levels on the same mesh.

7-21 bits 5-22 bits 13-27 bits 3-33 bits

Durham University

Steganographic capacity

Given a tolerance for the face normals, we can compute a bound for the steganographic capacity of the mesh geometry.

That capacity bound can be achieved with a simple LSB algorithm.

Steganographic capacity

For reasonable normal distortion tolerances the quantization levels of the original and the stego model are the same.

	$\epsilon = 0.1°$		$\epsilon = 1°$		$\epsilon = 10°$	
Heart	≈ 46.59	10	≈ 56.40	123	≈ 66.25	1509
Bunny	≈ 44.79	8	≈ 54.14	244	≈ 65.58	8759
Chair	≈ 39.26	35	≈ 49.46	0	≈ 58.66	82
Lucy	≈ 37.85	219	≈ 47.88	2005	≈ 57.73	19498
MPII Geometry	≈ 35.63	23	≈ 45.60	424	≈ 55.34	4466
Welsh Dragon	≈ 35.60	1068	≈ 45.00	125	≈ 54.01	4871

Thank you

Durham University