Rethinking the high capacity 3D steganography: Increasing its resistance to steganalysis

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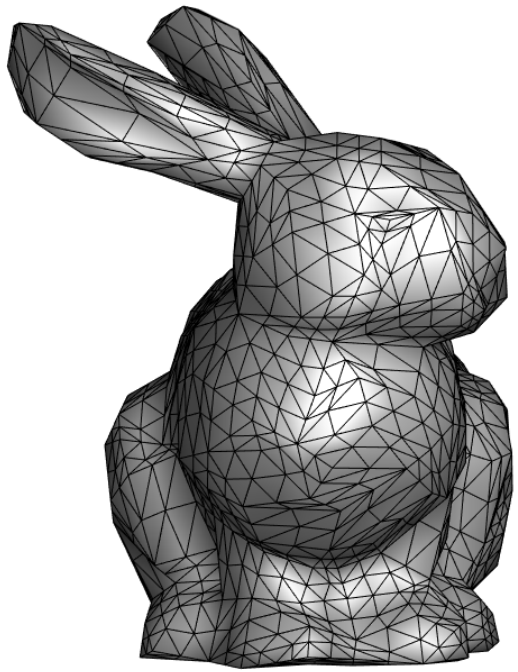
Introduction

- 3D steganography
  - Starts in 1997.
  - Conceals information in 3D objects.
- 3D steganalysis
  - Starts in 2014.
  - Detects if an information is hidden in a 3D object.



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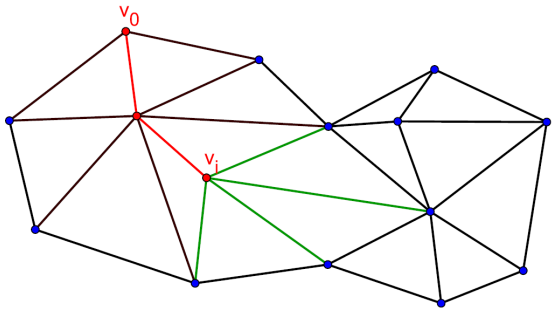
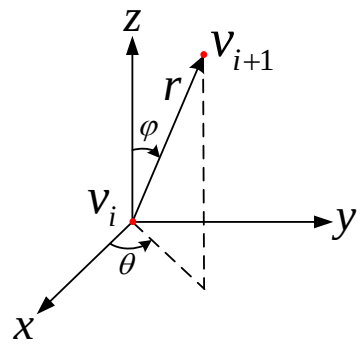
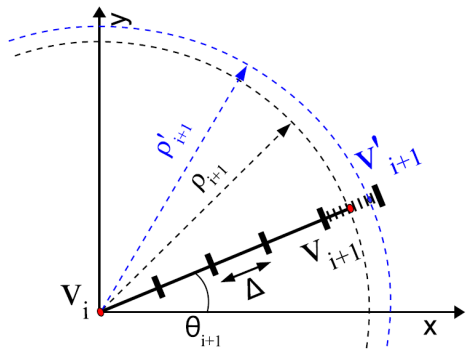
High capacity 3D steganography

Hamiltonian Path Quantization (HPQ) steganography

1. Build the Hamiltonian path over the complete graph of the vertices.
2. Quantize the path between v_i and v_{i+1} with interval Δ in the spherical coordinate system.
3. Each interval Δ is divided into s sub-intervals.
4. Embed information by modifying the spherical coordinates of v_{i+1}.







Itier V. and Puech W.(2016) *Multimedia Tools and Applications*.

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3D steganalysis

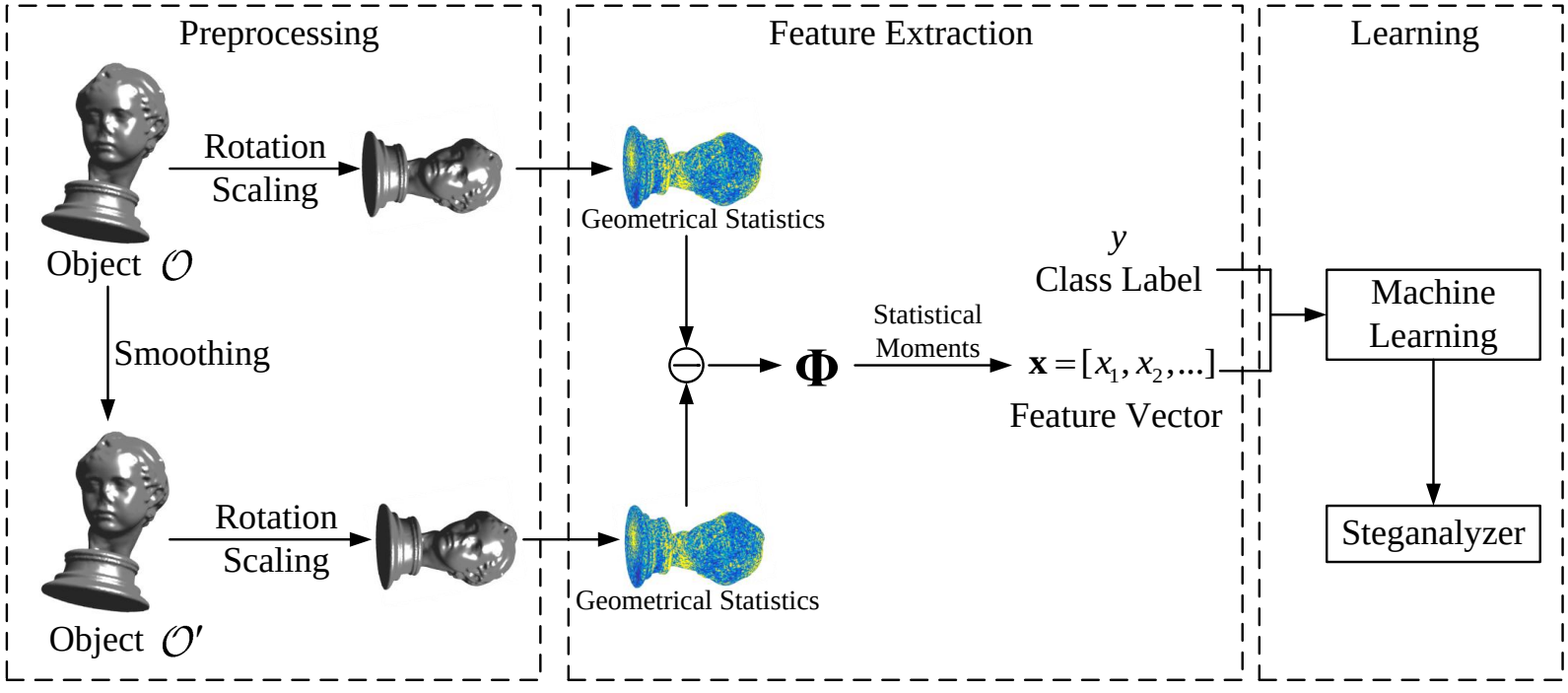

Figure: 3D steganalysis framework.

Yang, Y. and Ivrissimtzis, I. (2014) *ACM Transactions on Multimedia Computing, Communications, and Applications*.

Li, Z. and Bors, A. G. (2017) *Information Sciences*.

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Increasing the resistance of 3D steganography to steganalysis

Main ideas

- Reduce the distortion on the geometry of the 3D shape.
- Preserve the geometric statistics used for 3D steganalysis during the embedding.

Increasing the resistance of 3D steganography to steganalysis

The displacement of the vertex's radial coordinate is

$$D_\rho = \sum_{j=1}^{s} \sum_{k=1}^{s} P_j Q_k |j-k| \frac{\Delta}{s}, \tag{1}$$

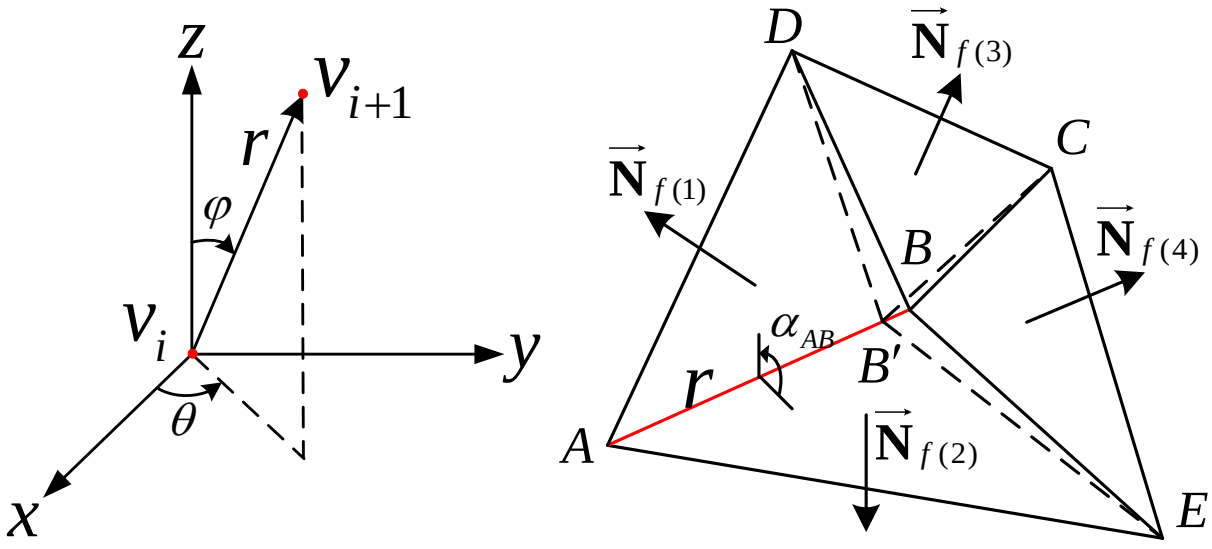
P_j: probability of vertex v_i in the j-th sub-interval;
Q_k: probability of modified vertex v_i in the k-th sub-interval.
Equation (1) is simplified as:

$$D_\rho = \frac{\Delta}{3}\left(1 - \frac{1}{s^2}\right). \tag{2}$$

Smaller interval Δ leads to smaller distortion.

Increasing the resistance of 3D steganography to steganalysis

Embedding in three coordinates or only one? Which one?



Modifications on the radial coordinate do not affect the face normals and dihedral angles.

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Experimental Results

Experiment Setup

- 354 3D objects from Princeton Mesh Segmentation project database, training/testing split: 260/94.
- Feature set: 52-dimensional Local Feature Set (LFS52).
- Classifier: Ensemble of Fisher Linear Discriminant (FLD).

Experimental Results

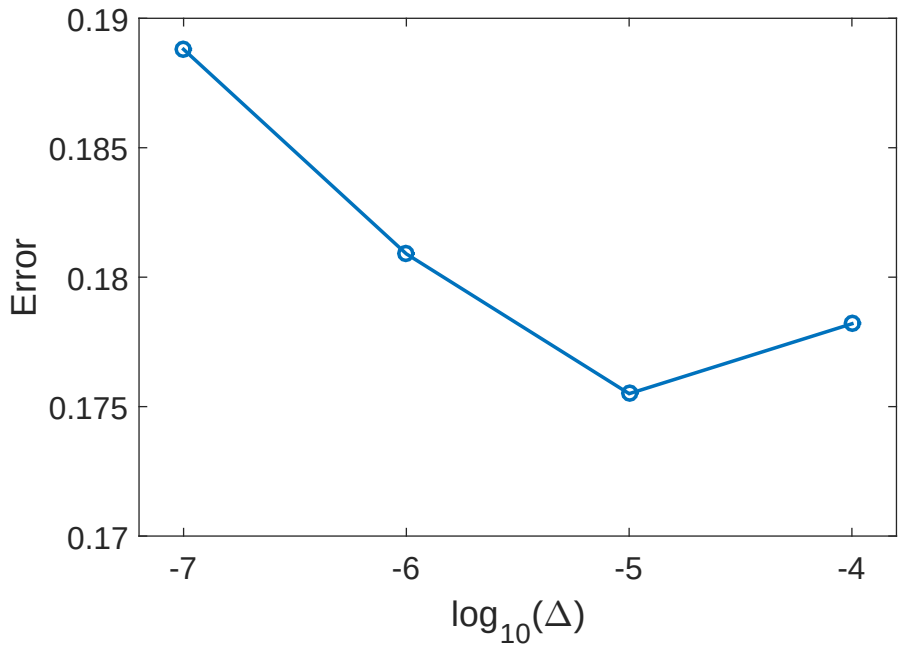

Figure: Detection errors for the steganalysis of the high capacity 3D steganography HPQ when varying the interval parameter Δ.

Experimental Results

- HPQ: Original algorithm that embeds in three spherical coordinates.
- HPQ-PA:Variant that embeds in the polar angle coordinate.
- HPQ-R: Proposed algorithm that embeds in the radial coordinate.

Table: Median values of the detection errors for the steganalysis of the 3D steganography (HPQ) and its variants, $\Delta = 10^{-7}$.

	HPQ (24 BPV)	HPQ-PA (8 BPV)	HPQ-R (8 BPV)	HPQ-R (24 BPV)
LFS52	0.1888	0.2553	0.3112	0.3085
Dihedral Angle	0.1866	0.3431	0.4400	0.4441
Laplacian	0.3545	0.3750	0.3800	0.3803
Curvature	0.3563	0.3963	0.4033	0.4069

Experimental Results

Compared to other information hiding algorithms

- MLS: Multi-Layers Steganoraphy.

  Chao, M. W. *et al*. (2009). A high capacity 3D steganography algorithm. *IEEE Trans. on Visualization and Computer Graphics*, 15(2), 274-284.

- MRS: A robust watermarking algorithm.

  Cho, J. W. *et al*. (2007). An oblivious watermarking for 3-D polygonal meshes using distribution of vertex norms. *IEEE Trans. on Signal Processing*, 55(1), 142-155.

- SRW: Steganalysis Resistant Watermarking.

  Yang, Y. *et al* (2017). A 3D steganalytic algorithm and steganalysis-resistant watermarking. *IEEE Trans. on Visualization and Computer Graphics*, 23(2), 1002-1013.

- HPQ: Hamiltonian Path Quantization steganography.

  Itier, V., and Puech, W. (2016). High capacity data hiding for 3D point clouds based on Static Arithmetic Coding. *Multimedia Tools and Applications*, 1-25.

Experimental Results

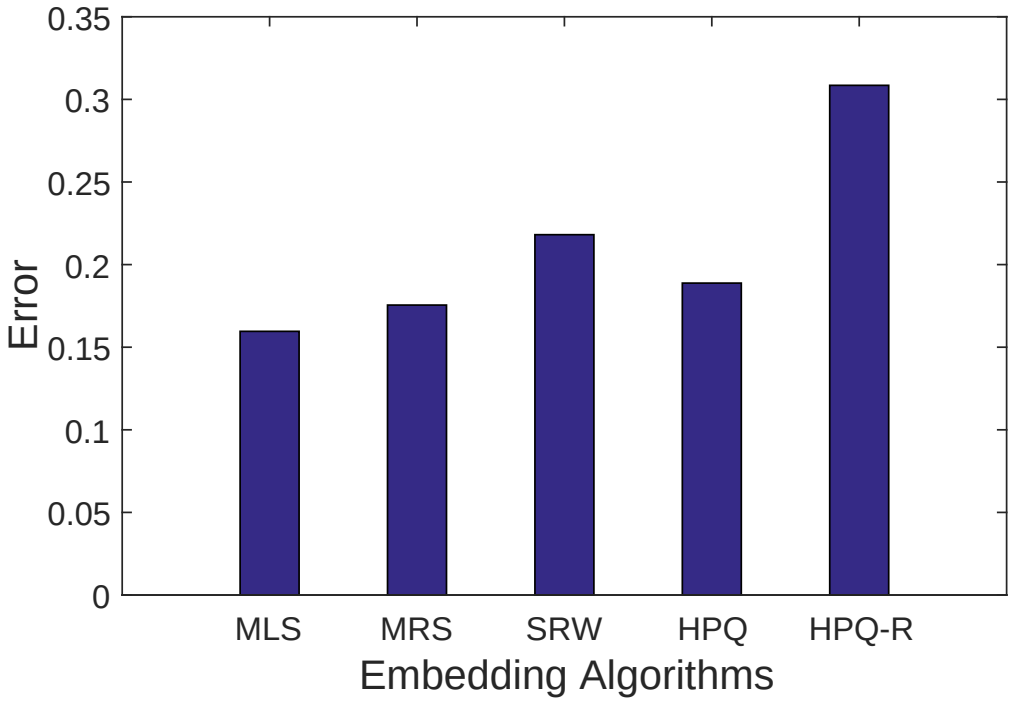

Figure: Detection errors for the steganalysis of embedding algorithms using the LFS52.

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Conclusion

- We analyze the influence of the embedding parameters on the shape distortion.
- We propose to only embed in the radial coordinate in the spherical coordinate system.
- We increase the resistance of the 3D steganography to steganalysis.

Thank you! Q&A