Watermarking 3D images and 3D meshes

Applications for cultural heritage

William PUECH

LIRMM
Laboratoire d'Informatique, de Robotique et de Microélectronique de Montpellier
UMR 5506 CNRS, University of Montpellier, France

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Outline

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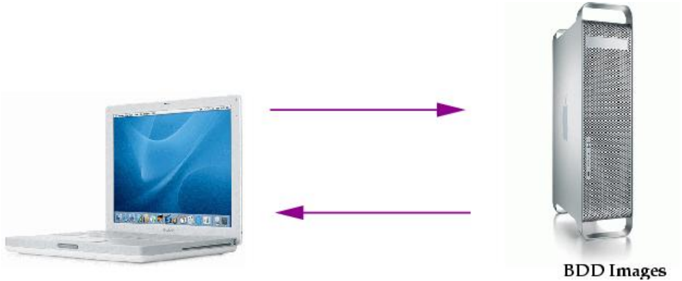
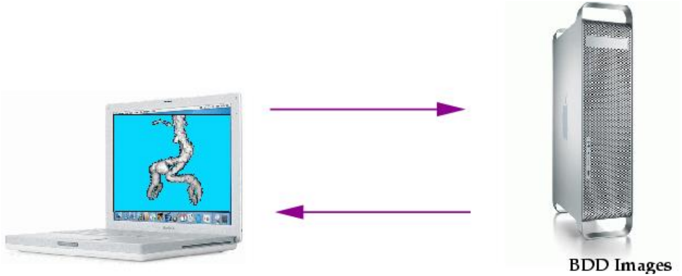
Safe visual data transfer: the problem



Safe transfer of visual data with high resolution.

Safe visual data transfer: the problem



3D Visualisation on line.

Safe visual data transfer: the problem

Safe Transfer and visualisation on line in real time for low powered systems (wireless devices).

Safe visual data transfer: the objectives

- To transfer safe visual data
  - To Have Confidential data **during** and **after** Transfer
  - To Ensure the Integrity (perceptual) and the Authenticity of data
  - To Hide associated data (high capacity) in Image
- To Access in different resolution levels of visual data
- To Process in Real Time
- To Reduce the data size.

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Possible solutions: data encryption or watermarking

Encryption or watermarking for safe visual data transfer

- Robust to noise
- Compatible with a compression
- Fast: access in real time
- The secret is based on a key (secrete or private key)
  - The Algorithm is known
  - Principle of Kerchhoffs [KER 83]
- Norms and standards

A. Kerckhoffs.
La cryptographie militaire.
Journal des sciences militaires, vol. 9, pp. 5–38, 1883.

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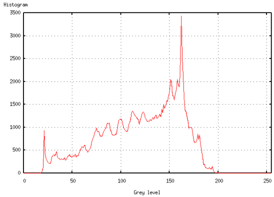
Safe Image Transfer

a) b) c)

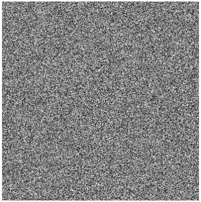
a) Original image.
b) Embedded image with a message of 512 bits using the DCT based data hiding method.
c) Difference between (a) and (b).

Safe Image Transfer

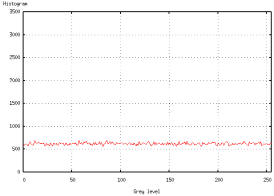
(a)



(b)



(c)



(d)

a) Original image, b) Original image histogram
c) Encrypted image with the stream cipher algorithm, with a key of 128 bits
d) Histogram of the image (c).

Safe Image Transfer

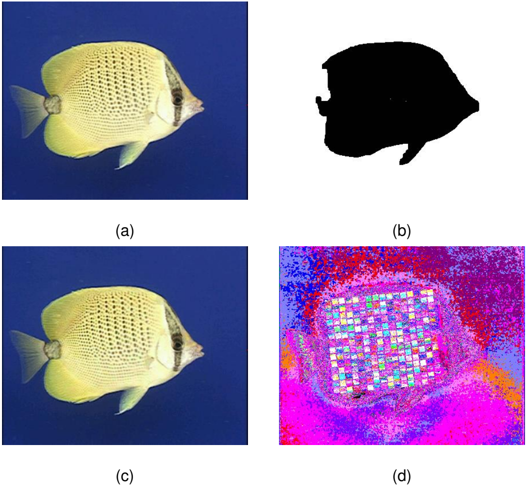
a)

b)

c)

a) Original image.
b) Transfer of compressed Image with a Safe ROI.
c) Reconstruction of the High Resolution Definition of the ROI.

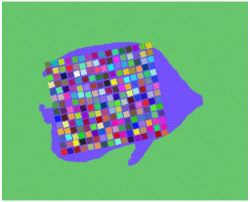
Safe Image Transfer



a) The original image, b) The associated binary mask, c) Color watermarked image, d) Difference between original color image and color watermarked image.

Safe Image Transfer

(a)



(b)

a) 5 degree rotation of color watermarked image "Fish", b) The label of fish color image with watermarked blocks.

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Data encryption

Data encryption

- The art to mask the data:
  - confidentiality : data protection
  - authenticity : emitter and receiver
  - integrity : ensure the totality and the content of the data
  - non repudiation : ACK

Perceptual signature: data integrity

Signature of a text

M1 = *"Aujourd'hui il fait beau dans le sud de la France, même si il y a un peu de vent..."*
S1 = `0x2534A8C08E12F4A8`
M2 = *"Aujourd'hui il fait beau dans le sud de la France, même si il y a un peu de mistral..."*
S2 = `0x3D68AB9310E38B51`

Signature of visual data

S1(original image (760 kB)) = S2(compressed image (224 kB))

Perceptual signature: data integrity

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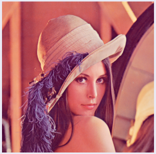

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Watermarking

Watermarking and Data Hiding

- The art to embed message in perceptual data:
  - invisibility: statistically invisible
  - no removable: robust to transformations and attacks
  - payload: size of the hidden message
- Data hiding: large payload
- Steganography: invisibility
- Watermarking: robust to attacks

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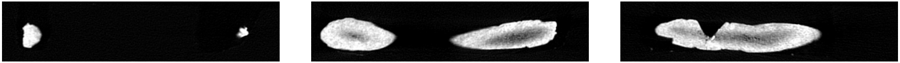
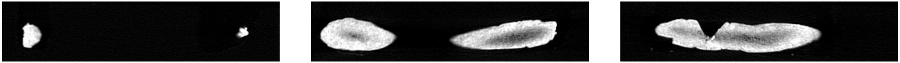
Image watermarking: LSB substitution



#17 #54 #83

Figure: 125 original slides of “Baton Percé”



#17 #54 #83

Figure: 125 watermarked slides of “Baton Percé”

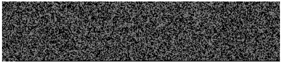
Image watermarking: LSB substitution

Analyze

- original size: 125 slides 382 $\times$ 82 pixels
- watermarking with a text file: 5.4 kBytes: PNSR = 70.5 dB
- watermarking with an image of 25.8 kBytes: PNSR = 63.8 dB
- watermarking with a 3D file of 472.4 kBytes: PNSR = 51.2 dB

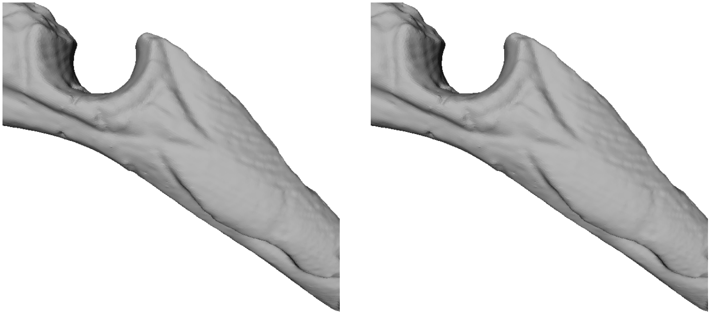
#17

#54



#83

Image watermarking: LSB substitution



(a) (b)

Figure: 3D Reconstruction: a) From the original data, b) From the watermarked data.

Outline

3D watermarking based on MST

References

P. Amat, W. Puech, S. Druon and J.P. Pedeboy
Lossless Data Hiding Method Based on MST and Topology Changes of 3D Triangular Mesh
Proceedings of the 16th European Signal Processing Conference, Lausanne, Switzerland, 2008

Algorithm

- MST construction,
- Search of quadruples,
- Selection of quadruples based on coplanarity and convexity,
- Embed one bit in each selected quadruple.

3D watermarking based on MST

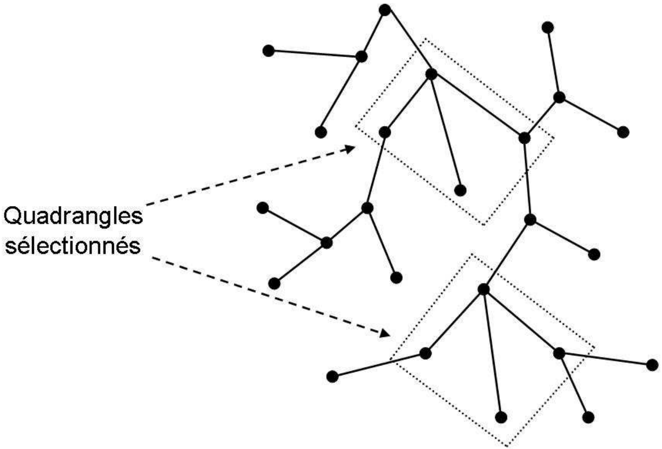


Figure: Selection of quadruples in the MST.

3D watermarking based on MST

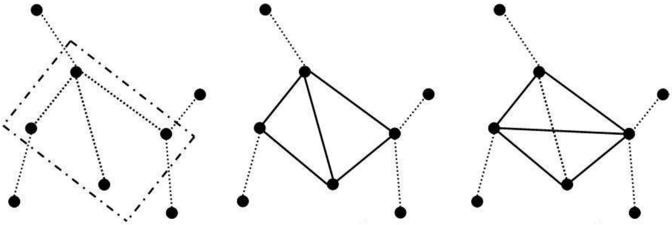


Figure: Data hiding of a 0-bit or a 1-bit.

3D watermarking based on MST

Advantages

- Global
- High payload
- Any modification of the vertex positions

Inconvenient

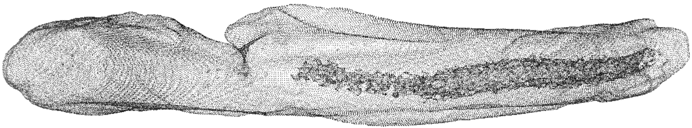
- No robust to noise

3D Watermarking

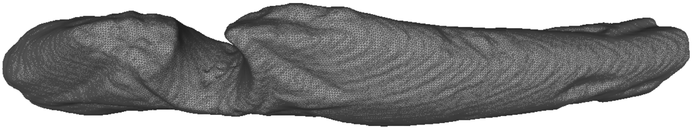
“Baton Percé”: 102173 vertices.

- With a threshold of 1 degree: message = 4466 bits (Hausdorff’s error = 0.001637).
- With a threshold of 30 degree: message = 21698 bits (Hausdorff’s error = 0.029063)

3D Watermarking



3D Watermarking



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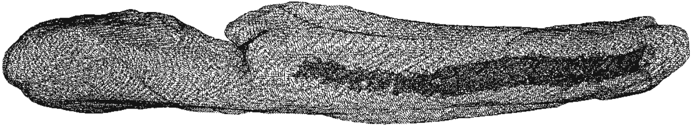
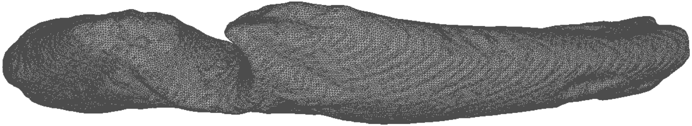
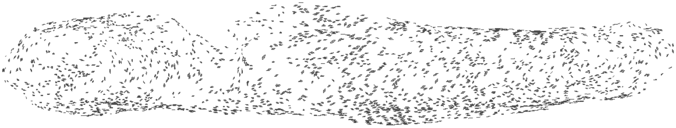


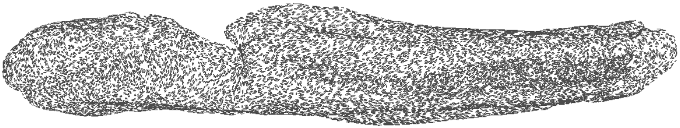
3D Watermarking



3D Watermarking



3D Watermarking



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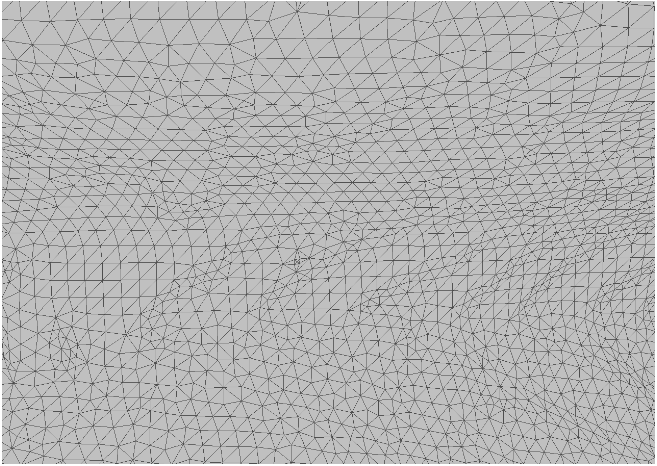

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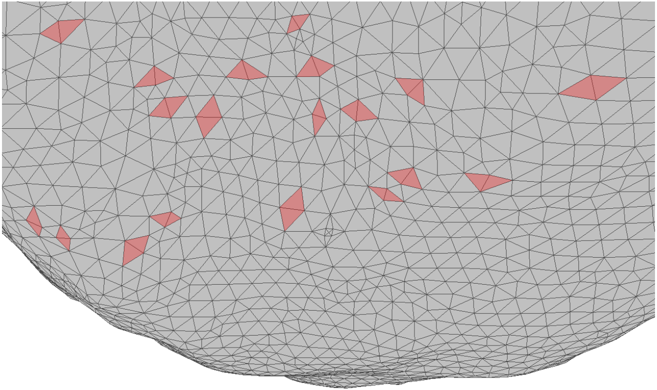

Robust 3D watermarking

References

F. Cayre and B. Macq
Data Hiding on 3D Triangle Meshes
IEEE Transactions on Signal Processing, 2003

Robust 3D watermarking

Algorithm

- Choice of a fisrt triangle ABC,
- Choice of a reference edge AB,
- Divide AB in several parts,
- Associate each part to a 0-bit or a 1-bit,
- Move the vertex C in order to have a projection of C on AB in a wished part.

Robust 3D watermarking

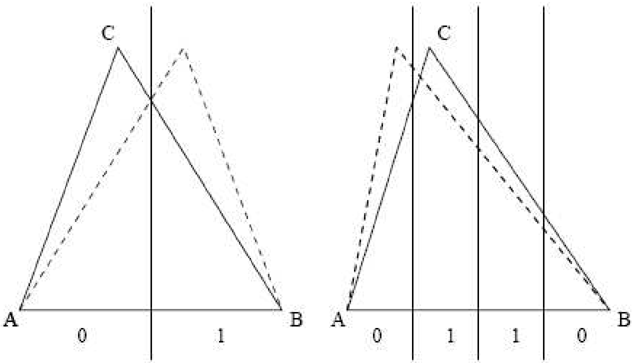

Figure: Overview of the method.

Robust 3D watermarking

Advantage

- Invisible
- Robust to noise

Inconvenient

- Local

3D Watermarking

(a) (b)

Figure: a) Original 3D object "Smilodon" 508796 vertices, b) Watermarked 3D object with 314071 bits (= 38.3 kBytes)

Outline

Conclusion

- Visual data protection is necessary,
- First proposed methods: *high payload but not robust to noise* or *robust to noise with a small paylaod*,
- But not robust to cropping for example.