Chapter 10

Conclusion

This thesis has presented the main issues related to the context of 3D shape watermarking. We have exposed the main applications making use of such data and their need of reliable copyright protection techniques. Among these techniques, we have restricted our work to blind watermarking schemes. The motivation of such choice has also been commented. We have mainly focused on watermark and watermarking attacks imperceptibility as well as on the development of robust blind watermarking schemes.

10.1 Contributions

The contributions of this thesis are the following:

1. a new perceptual image-based metric associated with a Mutual Information criterion
2. a blind and semi-fragile watermarking scheme based on spectral decomposition
3. a blind watermarking scheme robust against resampling attacks
4. a blind watermarking scheme robust against resampling attacks and cropping

10.1.1 Perceptual metric

We have proposed a new image-based metric in the context of 3D watermarking attacks. This metric has been validated by a psychovisual experiment for the four most common watermarking attacks on the four most used models in 3D watermarking papers. This metric has no limitations on 3D data representation type and behaves well when compared to the psychovisual experiment results. The drawback of this metric relates to the fact that it cannot be used for predicting the quality of 3D animated models.

Rondao Alface P. and Macq B., *Shape Quality Measurement for 3D Watermarking Schemes*, Electronic Imaging, Security and Watermarking of Multimedia Contents VIII, San Jose, California, 15-19 Jan. 2006.

Rondao Alface P., De Craene M. and Macq B., *Three-Dimensional Image Quality Measurement For The Benchmarking Of 3D Watermarking Schemes*, Electronic Imaging 05, Security, Steganography, and Watermarking of Multimedia Contents VII, San Jose, CA, Jan 2005.

Rondao Alface P., De Craene M. and Macq B., *Métriques de distorsion pour l´analyse comparative de schémas de filigranage 3D*, GRETSI 05, 20e colloque GRETSI sur le traitement du signal et des images, Louvain-La-Neuve, Belgium, 2005.

10.1.2 Blind semi-fragile watermarking scheme based on spectral decomposition

We have developed a blind and semi-fragile watermarking scheme by making use of the spectral decomposition of 3D meshes. The mathematical background of this transform has been presented. We have applied the provably good properties of the spectral decomposition to progressive transmission and watermarking purposes. The resulting watermarking scheme is very robust against modifications of the geometry but fragile against any modification of the connectivity. This scheme is also characterized by a high computational cost due to the eigenanalysis of large matrices.

Cayre F., Rondao Alface P., Schmitt F., Macq B. and Maître H., *Application of spectral decomposition to compression and watermarking of 3D triangle mesh geometry*, Image Communications - Special issue on Image Security, Vol. 18, No. 4, pp. 309-319, 2003.

Rondao Alface P., Cayre F. and Macq B., *Spectral decomposition of meshes and application to watermarking*, Proceedings of SPIE, Applications of Digital Image Processing XXVI , Andrew G. Tescher; Ed., 5203,

2003.

Cayre F., Rondao Alface P. and Maître H., *Compression and watermarking of 3D triangle meshes*, SPIE 47th Annual Meeting, Seattle, USA, July 2002.

10.1.3 Blind watermarking scheme robust against resampling

This work is based on the detection of robust umbilical points. This detection is based on the analysis of the curvature tensor topology. A multiscale analysis and a tensor filtering strategy have been used to overcome the problem of umbilical points due to noise and subsequent computation instabilities of the curvature hyperstreamlines. These points are then used to partition the 3D model through a geodesic Voronoi diagram and the dual Delaunay triangulation. The watermark embedding is based on spectral decomposition. If this scheme cannot resist against cropping, it is robust to geometric and resampling attacks. This scheme is limited to models representing differentiable and free-form surfaces.

Rondao Alface P. and Macq B., *Blind Watermarking of 3D Meshes Using Robust Feature Points Detection*, International Conference on Image Processing (ICIP05), Genova, Italy, 11-14 Sept. 2005.

Rondao Alface P. and Macq B., *Feature-Based Watermarking of 3D Objetcs: Towards Robustness Against Remeshing and De-synchronization*, Electronic Imaging 05, Security, Steganography, and Watermarking of Multimedia Contents VII, San Jose, CA, Jan 2005.

10.1.4 Blind watermarking scheme robust against resampling and cropping

The last scheme is based on 3D model prongs detection. These points correspond to extremities of the 3D surface. We have analyzed the pertinence of cropping attacks and motivated the choice of prongs to protect a model against this difficult attack. The watermark is embedded in local neighborhoods of these points by using a spatial technique. Based on statistical properties this scheme can resist against resampling and cropping. The drawbacks of this scheme are related to the computational cost and to the fact that the model must present extremities.

Rondao Alface P., Cayre F. and Macq B., *Blind and Robust Watermarking of 3D Meshes Using Feature Points Automatic Detection*, IEEE Trans. on Information Forensics and Security, *in preparation*.

10.1.5 Related Applications

This research work has also led to other contributions and publications.

We have developed a compression and progressive transmission scheme for 3D meshes using spectral decomposition. We have shown that visual quality of the first coarse resolution meshes is improved when compared to wavelet schemes. The method is however slow because of the computational cost of the spectral decomposition.

Rondao Alface P., Cayre F., Macq B., Schmitt F. and Maître H., *Lapped spectral decomposition for 3D triangle mesh compression*, ICIP 2003 - IEEE Signal Processing Society International Conference on Image Processing, Barcelona, Spain, 14-17 Sept., Vol. 1, 2003.

A tool for topological correction of 3D triangular surfaces has also been proposed for correct reconstruction of organ external isosurface. This work is mainly due to Sylvain Jaume.

Jaume S., Rondao Alface P. and Macq B., *OpenTopology: A Toolkit for Brain Isosurface Correction*, MICCAI 2005, 8th International Conference on Medical Image Computing and Computer Assisted Intervention, Palm Springs, California, USA, 26-30 Oct., 2005.

And finally we have proposed a detailed survey of 3D data hiding and watermarking schemes. This survey focuses on current trends and issues relative to this research domain such as impeceptibility and 3D watermarking applications requirements.

Rondao Alface P. and Macq B., *From 3D Mesh Data Hiding to Blind and Robust 3D Shape Watermarking*, LNCS Transactions on Data Hiding and Multimedia Security, March 2007, *accepted*.

10.2 Lines of Future Work

There are plenty of possible future work lines. The code of each of our contributions can be optimized to improve their results and computational costs. We would also like to compare the efficacy of spectral decomposition and of multiresolution analysis for watermarking purposes. The se-

cond scheme could be adapted to provide such a comparison. Concerning our metric, another psychovisual experiment based on several watermarking schemes could be interesting. Finally, we intend to include our contributions on a benchmarking platform.

Other applications can also benefit from the research presented in this thesis. Shape indexing could make use of umbilical points and prongs as fingerprints. These points can also be used as seeds for skeletonization and other shape analysis issues. The particular problem of molecular docking which consists in analyzing whether two shapes are locally geometrically complementar so that they can dock to each other, could also be tackled by detecting robust feature points.