3D Objects Watermarking and Tracking of Their Visual Representations

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***Abstract*—In the context of 3D watermarking, most of the state-of-the-art techniques analyze a 3D/3D approach where the insertion and the extraction of the mark take place over the object itself, whereas the most common use of 3D objects is done through its 2D projections or eventually stereovision. In this paper we present a work in progress in the context of 3D watermarking that introduces an asymmetrical approach 3D/2D which will allow the extraction of the mark without access to the 3D object. The extraction will be carried out from one or several 2D views with the aim of protecting the Intellectual Property Rights associated to the object in its projections.**

***Index Terms*—3D mesh; watermarking; visualization.**

I. Introduction

Over the last years the "digital rights management" (DRM) issue has been addressed for different types of information in order to protect the data from piracy [11]. 3D watermarking is a well known technique that is being introduced and combined with cryptography in current DRM systems. It consists in protecting the Intellectual Property Rights (IPR) related to a content by means of insertion of a secret mark in an imperceptible and also in a robust way.

Watermarking techniques provide rights protection for multiple contents: audiovisual documents, images, videos and 3D objects. 3D models are distinguished firstly by their usually associated irregular sampling and secondly by the fact that they deal with arbitrary geometry varieties (manifold) immersed in a threedimmensional Euclidian space. As a consequence of this particular nature the usual tools for signal processing commonly used by regular signals such as audio, image or video, cannot be directly applied to 3D objects. Accordingly, 3D watermarking techniques do not present the maturity of their equivalents for other types of contents.

In addition, the current watermarking algorithms generally insert a secret mark into the 3D model, and need this watermarked object to be able to detect or read the mark [5]. However, the most common use of 3D models is done through their visualization (2D or eventually stereo). For instance, 3D models are commonly used in image or video content, for example in 3D cinema via stereo or home entertainment applications using 3D meshes. While it is possible to reconstruct a 3D object from several of its 2D views, to decode the mark in this context is presently difficult or even impossible (see Fig. 1).

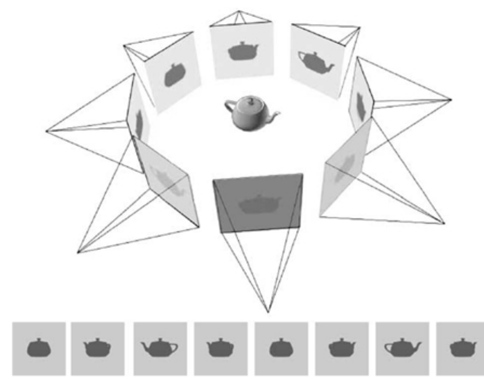

Fig. 1. The Teapot model and a set of projections depending on the angle of visualization. The model can be reconstructed from a certain number of its 2D representations.

This is the problem that we propose to address in this work. Contrary to the ordinary 3D watermarking techniques, for which the insertion and the extraction of the mark take place over the 3D model itself (3D/3D approach), we plan to develop techniques following an asymmetric approach 3D/2D in which the extraction of the mark could be done over one or several 2D projections of the 3D object without having access to the latter (see Fig. 2).

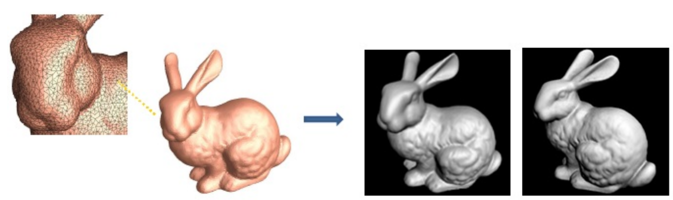

Fig. 2. The original Bunny 3D mesh and two of its 2D representations. The scheme we want to develop should provide the capability of reading the watermark from one or several representations of the object.

In this particular setting, we can name the pionneer work of J. Bennour et al. [1], who propose an insertion in the silhouette of a 3D object in several of its views belonging to image or video contents using this 3D object. This technique is able to detect the watermark only for certain views. However, given the fact that a minimal change in the visualization angle leads to a different silhouette along with the lack of knowledge of

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the orientation angles of the object in its visualizations, the object may not be protected. On the other hand, in the work presented by E. Garcia et al. [2], the 3D model is protected via its texture. The texture is defined by a set of images projected onto the object surface. However, this technique requires a texture rich enough to provide a robust watermark. Hence this results to a compromise between the texture richness and the robustness of the 2D hidden mark. These original methods still present limitations in both theoretical and application levels which this work intends to study.

This paper is organized as follows. The second section introduces the industrial applications of the techniques we will develop. The third section is devoted to present the proposed work and the way we plan to address it. The last section presents the conclusions.

II. Applications

Digital watermarking finds already applications related to image and video content. The most suitable application is copyright protection, where the watermark identifies the buyer of the digital content. This mechanism allows to prevent piracy by discouraging people to make illegal copies of a protected content.

3D multimedia content has also to be protected. 3D watermarking finds industrial applications such as 3D cinema, 3D videoconference, video games, home entertainment or augmented reality applications in smartphones. The idea is to protect the intellectual property rights of 3D meshes as well as their visualization.

In this particular work, the proposed watermarking schemes of 3D content respond to several cases of different applications. Among them, 3D watermarking based on Quantization Index Modulation (QIM) is suitable in a blind and semi-fragile context, and it is useful in data authentication applications.

The 3D watermarking technique making possible a detection from a certain number of 2D representations of the object is useful for copyright protection tools in the case of a 3D object immersed in 2D video or 3D stereo content. This need suits several domains: digital cinema, video games or home entertainment, audiovisual content players (for example Blue-Ray) or screens and stereovision glasses used to visualize 3D content.

On the other hand, this work will study the projections more suitable to watermark in order to protect the whole 3D model. In particular, the analysis of feature points or lines, roughness properties and local texture on the surface will be performed. This offers new perspectives in the watermarking of 3D physical objects either immersed or not in an augmented reality environment, like 3D videoconference or mobile applications in smartphones related to the 3D navigation.

III. Proposed Work

Presently there exist several schemes which provide a robust protection of the intellectual rights of a 3D object by embedding a secret and imperceptible mark [4]. But there is a lack of protection of the digital rights of visual representations of 3D models.

This work will focus on the extraction of the information (originally hidden into a 3D model) from one or several views of the object, with the interest of protecting the intellectual rights associated to the model in its 2D visual representations. Figure 3 summarizes the scheme of our work.

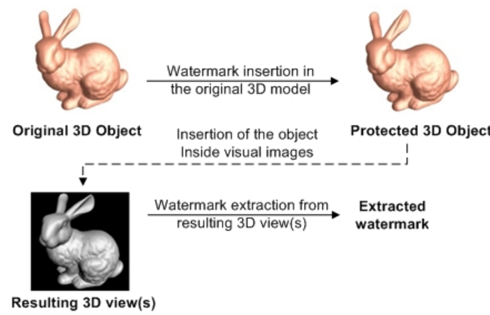

Fig. 3. A secret mark is first inserted in the 3D original model, protecting the content. The watermarking scheme has to be able to resist the visualization transformation and recover the mark from one or several 2D representations of the object.

Given the uncertainty related to the angles (2D views) in which the 3D object will be visualized, the use of silhouettes as in the work presented by J. Bennour et al. [1] does not seem as an optimal choice, since a slight variation in the direction of view would completely modify the silhouette.

We plan to perform an automatic detection of robust feature points in the 3D object around which robust neighbourhoods will be defined, performing local watermarks along the surface. Feature points detection together with neighbourhood definition could be based on the results presented in the work by P. Rondao Alface et al. [4]. To insert the mark we plan first to make use of the Spread Transform Dither Modulation (STDM) technique [3]. STDM is a variant of QIM technique and present good properties in the frame of 3D blind watermarking. Other variants of QIM will be tested for performing the insertion, as well as other state-of-the-art techniques, either in the spatial or the spectral domain, evaluating their pertinence in the frame we are dealing with.

Since there are many parameters for visualizing a 3D mesh (rendering, angle, texture, resolution, etc), we will address the problem step by step, defining a scenario with the simplest conditions in the first instance, and building increasing complexity models afterwards. The impact of the rendering process can be seen in Figure 4, which shows the rendering when using different shading techniques. As a matter of fact, different parameters in the rendering (shading, lighting models, etc) will have different impacts over the watermark which will be evaluated. We plan to develop a model of the visualization attack that the 3D object undergoes in the 2D to 3D transformation. We will study the distortion the model undergoes and the impact on the watermark. This model will extend the works discussed in [1, 2] and will be based on the analysis of the whole transformation chain that a 3D object undergoes from the watermarking process until the complete or partial reconstruction from its visualization in 2D.

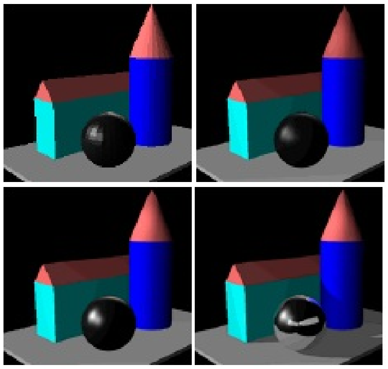

Fig. 4. From left to right: the same scene rendered with flat shading, Gouraud shading, Phong shading and Ray Tracing respectively (data courtesy of [9]).

One of the important steps is based on the use of depth maps, which can be for example obtained from stereovision. Depth maps give information of the depth of every pixel of the 2D view. Hence these depth maps provide part of the 3D mesh structure and should help in recovering the mark. The issue can then be brought to the case of ”cropping” of the 3D object as well as a regular remeshing (resampling of positions of 3D points), depending on the resolution and accuracy of the depth estimation (see Figure 5). However, whereas the state-of-the-art blind and robust 3D watermarking schemes already withstand combinations of a wide variety of attacks (noise addition, simplification, smoothing, etc), there is a lack of blind schemes which can withstand the cropping attack and the subsequent de-synchronization. We will study in particular the state-of-the-art methods for depth map reconstruction from several projections as well as the impact of the resolution (image) of the captured views, and possibly the impact of their compression [6, 7, 8]. As a matter of fact, topological errors may appear due to obstructions when there is not enough number of used views, such as the presence of holes or disconnected parts of the mesh. Few watermarking schemes provide resistance to this kind of errors in the mesh reconstruction [5].

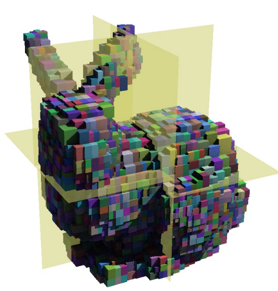

Fig. 5. A simulation of the Bunny model after the visualization process. The depth component for every pixel of the image resulting from the projection transformation is represented by blocks. The problem can be brought to the case of ”cropping” of the 3D Bunny model together with a regular re-sampling attack (data courtesy of [10]).

Other factors likely to influence the reconstruction accuracy, the selection of the views or the watermarking robustness, such as the presence of textures, the surface curvature and roughness and the presence of edges, feature points and feature lines, will be as well examined in detail subsequently in order to refine the watermarking algorithms.

The goal is thus to determine if the mark can be detected from a number of views lower than what is required to reconstruct the 3D object (without watermark) with good quality.

Subsequently this technique could be extended to animated 3D objects as well as the study of the impact of the 2D views resolution and their compression (for example via JPEG) over the robustness of the watermark. Another possible extension consists in the evaluation of the watermarking of solid objects which are later numerized (from one or several 2D representations) with the intention of their use into augmented reality applications.

IV. Conclusion

In this paper, we presented a work in progress based on the protection of the intellectual rights of 3D objects through their 2D projections. Since the most common use of 3D models is done through their visual projections in 2D or stereovision, we plan to develop 3D watermarking schemes able to resist the visualization process undergone by the object during the 3D to 2D transformation. This will help to protect the 3D models in its 2D representations.

References

[1] J. Bennour and J.-L. Dugelay. *Protection of 3D object visual representations*. ICME 2006, IEEE International Conference on Multimedia & Expo, July 9-12, 2006, Toronto, Canada, pp. 1113-1116

[2] E. Garcia and J.-L. Dugelay. *Texture-based watermarking of 3D video objects*. IEEE Transactions on Circuits and Systems for Video Technology, vol. 13, no. 8, pp. 853-866, Aug. 2003.

[3] R. Darazi, R. Hu, and B. Macq. *Applying spread transform dither modulation for 3D mesh watermarking by using perceptual models*. In International Conference on Accoustic Speech and Signal Processing 2010. ICASSP 2010. IEEE International Conference on, pp. 1-5 Mar. 2010.

[4] P. Rondao Alface, B. Macq, and F. Cayre. *Blind and robust watermarking of 3D models: How to withstand the cropping attack?*. In Image Processing, 2007. ICIP 2007. IEEE International Conference on, 5, pp. V-465 - V-468, Sept. 2007.

[5] P. Rondao Alface and B. Macq. *From 3D Mesh Data Hiding to 3D Shape Blind and Robust Watermarking: A Survey*. T. LNCS Transactions on Data Hiding and Multimedia Security 2:91-115, 2007.

[6] C.H. Esteban and F. Schmitt. 2004. *Silhouette and stereo fusion for 3D object modeling*. Computer Vision Image Understanding, vol. 96, no. 3 (Dec. 2004), pp. 367-392, 2004.

[7] N.D.F. Campbell, G. Vogiatzis, C. Hernandez, and R. Cipolla. *Automatic 3D object segmentation in multiple views using volumetric graph-cuts*. In 18th British Machine Vision Conference, vol. 1, 2007.

[8] Y. Yemez and C.J. Wetherilt. *A volumetric fusion technique for surface reconstruction from silhouettes and range data*. Computer Vision and Image Understanding, vol. 105, pp. 30-41, 2007.

[9] A. Oebbeke. http://www.glossar.de.

[10] V. Lu. https://netfiles.uiuc.edu/victorlu/www.

[11] S. Haber, B. Horne, J. Pato, T. Sander, and R. E. Tarjan. *If Piracy is the Problem, Is DRM the Answer?*. in E. Becker, W. Buhse, D. Gnnewig and N. Rump (Ed.): Digital Rights Management - Technological, Economic, Legal and Political Aspects. Heidelberg: Springer-Verlag, pp. 224-233, 2003.