ABSTRACT

In this paper, the authors present a robust three-dimensional fingerprint algorithm for verification, indexing, and identification. The core idea behind our technique is to apply the eigen-decomposition to the mesh Laplacian matrix, and then compute minimum spanning trees (MST) of several concentrations of the mesh shape structure. The fixed size hash vector of a 3D mesh is defined in terms of the MST values and number of the initial patches. The extensive experimental results on several 3D meshes prove the uniqueness of the extracted hash vectors and the robustness of the proposed technique against the most common attacks including distortion-less attacks, compression, noise, smoothing, scaling, rotation as well as mixtures of these attacks.

Keywords: 3D Attacks, 3D Fingerprinting, 3D Hashing, Eigen-Decomposition, Robustness, Spectral Graph

1. INTRODUCTION

The usage of digital multimedia data such as movies, television broadcasts, 3D models and similar digital products has grown rapidly over the last few years. Nowadays it is easier for multimedia element to be transmitted over the internet. Obviously, the data could be entirely photocopied or customized and retransmitted. Thus digital copyright protection and fingerprinting to ensure the authentication and the integrity of multimedia elements has long been

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the core of the digital data security research. Its importance is growing quickly due to the increasing problem of the illegal replication and the prohibited digital content modification.

The problem of 3D object hashing and watermarking is relatively new field as compared to 2D watermarking and hashing (Cox, Miller, & Bloom, 2002; Mihak & Venkatesan, 2001; Venkatesan, Koon, Jakubowski, & Moulin, 2000; Swaminathan, Mao, & Wu, 2006; Fridrich, 2000; Abdallah, Hamza, & Bhattacharya, 2006; Lin, Zsu, Oria, & Ng, 2001). It has received less attention partially because the technology that has been used for the 2D images and videos analysis cannot be easily adapted to 3D objects. Moreover, 3D meshes can be effortlessly altered by several graphics attacks without changing the general shape of the model.

Hash functions could assist in guaranteeing the authentication and the integrity of the multimedia element. The authenticity of the digital data can be verified by recalculating the fingerprint value from the underlying data and judging it against the attached fingerprint value (Fridrich, 2000; Abdallah et al., 2006). In addition, the multimedia hashes are used in content-based recovery from databases (Lin et al., 2001).

There has been significant research on image hashing for more than a decade. In Venkatesan et al. (2000) a robust image hashing is introduced. The algorithm employs arbitrary signal processing approaches for a nonreversible compression of images into random binary strings. Experiments show robustness against image changes due to compression, geometric distortions, and other attacks. Fourier transforms features and controlled randomization was used in (Fridrich, 2000) to generate a robust image hash. In (Mihak & Venkatesan, 2001) an image hashing prototype that employs geometric skins is proposed, it creates unpredictable randomized output. The technique has been modified for robust multimedia classification, identification and watermarking. Another image hashing technique is presented in (Monga & Evans, 2006), where several feature points is extracted for perceptual image hashing. The chosen feature points maintain the geometry and steady to perceptually irrelevant deformations. Statistical analysis is employed for image hashing and watermarking (Cannons & Moulin, 2004), where the hash is chosen from undisclosed division of the discrete cosine transforms of an image and the watermark is embedded using multiplicative technique.

Unlike images, 3D hashing and watermarking is much harder, given that a small change on the 3D mesh geometry would extremely damage the embedded watermark or change the mesh fingerprint (W. Berchtold & Steinebach, 2014). Early algorithms on 3D watermarking (Benedens, 1999) consist of embedding the watermark information directly by modifying either the 3D mesh geometry or the topology of the triangles. These methods are usually simple and require low computational cost. Nevertheless, the main problem of these techniques is the limited robustness against attacks. Lately, numerous watermarking techniques are proposed to embed in the frequency domain (Praun, Hoppe, & Finkelstein, 1999; Ohbuchi, Takahashi, Miyazawa, & Mukaiyama, 2001; Abdallah, Hamza, & Bhattacharya, 2009). The idea is based on spectral decomposition and wavelet transform. These methods show good resistance against attacks. In (Ohbuchi et al., 2001), a watermarking algorithms based on the mesh spectral matrix is proposed, where the watermark is embedded by altering the low frequency component of the spectral coefficients. More robust technique based on spectral domain is proposed in (Abdallah et al., 2009) and (Abdallah, Hamza, & Bhattacharya, 2008), the watermarking algorithm employs the eigen-decomposition and the nonnegative matrix factorization. The idea is to use the nonnegative matrix factorization to several blocks of the spectral matrix for a 3D object. In (Karni & Gotsman, 2000) the mesh Laplacian matrix was used to convert the 3D model into a reduced size representation. This was done by retaining the smallest eigen-values and associated eigen-vectors which contain the highest concentration of the shape information.
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