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A Brief Survey on 3D Watermarking Techniques

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Abstract—*This paper discusses a brief survey on the various existing techniques for 3D watermarking, categorizing into two groups viz.robust 3D watermarking and fragile 3D watermarking. The technique of hiding some information into the 3D graphical models or 3D images or 3D videos in such a manner that the watermarked 3D model is indistinguishable from the original ones is known as 3D watermarking. It has become one of the important areas of research nowadays because of the advanced development of 3D technology, growing multimedia over the Internet, misuse of videos, images in the real world etc. Robust 3D watermarking focusses on ownership identification and allowing the watermarks detectable even after different watermark attacks whereas fragile 3D watermarking relies its importance to content authentication and content verification. Any 3D watermarking system may be subjected to various attacks viz. translation, rotation, scaling, noise attacks, re-triangulation etc. and any watermarking system should be able to resist to such attacks.*

1. INTRODUCTION

With the advanced development of 3D technology and the fast growing of the Internet, the copyright protection or the content protection or authentication of 3D images or videos has become a necessity and now considered an area of prime importance. 3D watermarking is the technique of hiding some information into the 3D models or 3D images or videos either in the spatial or frequency domain and it is one of the solutions for the above purpose. Generally, 3D watermarking is the technique of embedding or hiding information into audio, image or videos for different applications such as copyright protection, Digital Rights Management (DRM), content authentication etc. Watermarking techniques can be categorized into the following:

- Based on working domain: spatial and frequency.
- Based on the type of document to be embedded: text, images, audio, and videos.
- Based on Human perception: visible watermark, invisible robust watermark, invisible fragile and dual.
- According to application: Source-based and Destination based.
- According to the type of information needed at the time of extraction: blind and non-blind.

The various properties of a general watermarking system are:-

- Effectiveness: It is the property of a watermarking system which should be able to correctly detect the embedded or hidden message.
- Image fidelity: It is the property to keep the degradation in image quality to the minimum after embedding a hidden message.
- Payload size: The size of the image that is to be hidden may require a relatively big payload to be embedded in a cover work.
- False Positive Rate: It is the number of digital works that are identified to have a watermark embedded when in fact they have no watermark embedded. False Positive rate should be very low for any watermarking system.
- Robustness: The ability of the system to withstand various attacks such as cropping, noise, compression, rotation, scaling and translation etc.

3D Watermarking Technique consists of Embedding of Watermark and Extraction of the same watermark. The properties of various digital watermarks are perceptually invisible, robustness, cost, capacity, recoverable, reversible, undetectable, able to determine the true owner, high bit rate etc. In addition to the above general digital watermarking characteristics, the important criteria that a 3D watermarking should consider is the capacity i.e. the amount of geometric objects that the 3D models form and the watermark content. Also, transformation processes viz. translation, rotation, scaling etc., noise attacks, re-triangulation are some of the attacks that may be encountered in 3D watermarking. Any 3D watermarking system should be able to withstand majority of these attacks.

The performance of any watermarking system can be evaluated based on the following criteria:

(i) PSNR values: Peak signal to noise ratio for measuring the quality of the watermarked image, which is calculated as:

$$PSNR = 10 * \log((M * M)/MSE),$$

Where M=1 for double precision floating point image data and M=255 for 8 bit unsigned integer data type.

MSE= $(\sum(I_1\ (m,n) - I_2\ (m,n)))^2/$ (M*N),

$I_1(m,n)$ is the cover image and $I_2(m,n)$ is the watermarked image, each of size M*N.

(ii) NCC: Normalized Correlation Coefficient for measuring the similarity and difference between the original and the extracted watermark under various attacks, which is calculated as:

$$NCC = \frac{\sum\sum(A-\mu_A)(B-\mu_B)}{\sqrt{(\sum\sum A-\mu_A)^2(\sum\sum(B-\mu_B)^2}}$$

where μ_A and μ_B are the mean of original watermarked image, A and the extracted watermark image,B respectively, each of size M*N..

The paper is organized as follows. Section 2 discusses on Robust 3D watermarking, Section 3 is on Fragile 3D watermarking followed by Conclusion in section 4.

2. ROBUST 3D WATERMARKING

The main aim of robust watermarking is to indicate ownership and to allow the watermarks detectable even after different watermark attacks. Robust 3D watermarking is again classified into blind and non-blind techniques. Discussed below are some of the existing robust 3D watermarking techniques. Most of the watermarking techniques are of blind methods.

A novel non-blind 3D watermarking method is proposed based on Geometry Image and robust against affine transformations, noise addition, smoothing, resampling, cropping. This method uses DCT transform in a color image for embedding [1].

Cai et.al proposed a blind robust watermarking scheme in which three novel blind spatial watermarking methods viz. OTP-W, OTC-W and Zero-W) for arbitrary 3D meshes based on Octree are proposed. OTP-W and OTC-W have a large embedding space to embed a binary image and a RGB image, a method which is robust against translation, rotation, uniform scaling and vertex reordering attacks with blind detection. Using Octree in Zero-W, Zero watermark is constructed to resist attacks of simplification, noise and remeshing [2].

Chen et.al proposed a blind and robust watermarking scheme for 3D Triangular Mesh Models using the concept of 3D Edge Vertex Detection in which the watermark is hidden within the 3D graphical object modifying a subset of carefully selected edge vertices in order to resist against various attacks such as noise, 3D rotation, cropping and other combined attacks [3].

A blind watermarking algorithm of 3D models and objects is proposed in which a string of bits is generated based on a key and is embedded in the geometrical structure of the graphical object altering the locations of certain vertices. A minimal visibility of the distortions in the watermarked object is ensured by a bit encoding of 1 positions a vertex inside a volume modelled by the geometry of its neighborhood while a bit encoding **0** positions the vertex outside such a volume [4].

A blind 3D watermarking method based on a wavelet transform, a fuzzy inference system and multiresolution representation (MRR) of the 3D model is developed in which the watermark to be hidden is scrambled by Arnold transform and embedded in the wavelet coefficient at the third resolution level of the MRR and the invisibility of the watermark is accomplished by the fuzzy logic [5].

A blind robust 3D mesh model watermarking applications is proposed in which a pseudo-random watermark is embedded in the 3D mesh model deforming geometrically its vertices, without alluring the vertex topology. Prior to embedding and detection a set of simple transforms is applied to the 3D mesh model and the watermark sequence is embedded in a set of vertices for mesh simplifications [6].

A robust blind watermarking method is implemented by embedding the watermarks in modified texture mapping information using texture image compensation technique and robustness is achieved using Neighbor Couple Embedding (NCE) incorporated with Manifold Harmonics Transform (MHT) [7].

A robust blind watermarking method is implemented by embedding the watermarks into a 3D mesh model adjusting the order of vertices in each triangle and the normal vertex of each triangle is kept unchanged [8].

A robust blind watermarking method is proposed for irregular as well as regular 3D triangle surface meshes in which watermark is first processed using vertex and face-reordering process, embedded into the modified L2 norm of the wavelet coefficients various multi-resolution levels and extracted after applying the same preprocessing step used in embedding [9].

Yang et.al proposed a robust blind 3D watermarking method for polygonal meshes using modified Laplacian co-ordinates in which the watermark is embedded into the histogram of the Laplacian co-ordinates [10].

Song implemented a robust blind 3D watermarking method where the conventional 2D DCT is used in embedding the watermark, according to which the vertices of the 3D mesh models are moved [11].

Based on spread spectrum method of watermark embedding, a robust watermarking of 3D models is proposed by Mihai [12].

A non-blind robust watermarking scheme for 3D models in the spatial domain is developed in which the embedding of a watermark bit is done by the vertex norms in one vertex set which is prepared by converting the Cartesian coordinates of 3D model vertices into spherical coordinates and partitioning, sorting them .The same watermark bit is embedded repeatedly into various vertex sets. The classification and modification of vertices are separated to avoid desynchronization problem. The watermark bit is extracted based on the number of vertices satisfied with specified conditions, comparing the detected model and the original model [13].

Praun et.al proposed a robust watermarking for triangular meshes using spread spectrum approach constructing a set of scalar basis function over the mesh vertices utilizing a multiresolution analysis and embedding the watermark by perturbing vertices along the direction of the surface normal, weighted by the basis functions [14].

Implementing the spread spectrum technique to the 3D polygonal models, a robust semi-blind and semi-reversible watermarking scheme is implemented, which is robust against RST transformations, noise addition, smoothing, mesh simplifications, vertex reordering etc. [15].

Tawfiq et.al proposed a robust watermarking technique of digital vector maps for copyright protection by inserting additional vertex coordinates between adjacent vertices which locations are governed by the value of the watermark data. After embedding the watermark operation, which involves the map topology is preserved as well as provides the users a means to control the distortions [16].

A robust non-blind watermarking of 3D models is proposed utilizing the local smoothness variation of the mesh which is calculated by the average angle difference between the surface normal and the average normal in which vertices of the moderate smoothness variation are selected for embedding a random watermark [17].

Singh et.al also proposed a novel non-blind robust watermarking using vertex normal in which the size of the vertex normal is altered according to the watermark bit to be used for embedding [18].

Yonggang Fu proposed a robust image watermarking scheme which utilizes 3-dimensional discrete cosine transform (3D DCT) for color image copyright protection. In this system, the color image is divided into 3-D blocks, and then transformed into transform domain by 3D DCT transform into which the generated pseudo random sequence is embedded. The watermark is embedded applying the nice correlatives among different color channels, with good robustness [19].

Smita Jagdishprasad Jaipuria presented a robust watermarking scheme for DIBR 3D images by quantization on wavelet transform coefficients with consideration of imperceptibility for content protection of DIBR images [20].

Ivy et.al developed a robust, blind watermarking scheme for three dimensional (3-D) anaglyph images where 3-D Discrete Wavelet Transform (3-D DWT) is used to decompose the image and processed directly. The watermark to be embedded is computed from the image. Jacket matrix is used for simplicity in the watermark embedding and extraction processes. It is also discussed and shown in the paper that the proposed scheme is highly imperceptible and robust against various image processing and signal processing attacks [21].

Kim et.al proposed a robust watermarking scheme for DIBR 3D images using quantization on dual-tree complex wavelet transform (DT-CWT) coefficients. Approximate shift invariance and directional selectivity is employed to select certain coefficient of sub-blocks and the coefficient rows are grouped based on the properties of DIBR. During extraction, the threshold is carefully chosen with a low false positive rate. It is shown in this paper that the embedded watermark can be stably extracted from the center view and the synthesized left and right views, even if the synthesized left and right views are distorted by general attacks. Also, the proposed scheme is also shown to be robust to pre-processing of the depth image and baseline adjusting [22].

Kalivas et.al proposed a novel technique for 3D model watermarking robust against geometric transforms which uses the center of mass and the principal component of the model in order to transform the data to a space, not affected by geometric transformations viz. translation, rotation and scaling [23].

A robust watermarking algorithm with informed detection for 3D polygonal meshes is presented by Ohbuchi et.al. using mesh-spectral analysis to modify mesh shapes in their transformed domain to embed much larger meshes within a reasonable time, and that the watermark is robust against connectivity alteration. Also the watermark is robust against attacks that combine similarity transformation with cropping, mesh simplification, and smoothing [24].

Tefas et.al proposed a novel blind method for 3D image watermarking for copyright protection which is robust against geometric distortions in which a ternary watermark is embedded in a grayscale or a color 3D volume which enables fast and robust watermark detection even after undergoing geometric distortions of the watermarked volume and robust against lossy compression of the 3D data [25].

3. FRAGILE 3D WATERMARKING

Fragile watermarking mainly emphasize on authentication and content verification. It is used for tamper detection also. In this section, some existing fragile watermarking techniques are discussed in brief.

Arun et.al developed a novel blind multiple watermarking scheme for content protection problem of DIBR 3D images. It is also discussed in this paper that mutually orthogonally reference patterns for multiple water mark embedding, and proper embedding order plays an even more important role in watermarking the DIBR 3D images [26].

Lin et.al proposed a novel blind multiple watermarking scheme to deal with the content protection problem of DIBR 3D images. It is also mentioned that for multiple watermark embedding proper embedding order plays an even more important role in watermarking the DIBR 3D images. The proposed scheme is robust against the JPEG compression and noise adding attacks and can also tolerate large range variations of the depth image during rendering [27].

Ramya et.al proposed a semi-fragile watermarking algorithm for 3D models in which the watermark is embedded modifying the integral variants of some of the vertices shifting a vertex and its neighbours.All the vertices for the embedded information are tested and combine for extraction [28].

A novel fragile watermarking algorithm is proposed in which perceptible distortion overcomed by modifying every vertex location in the model is using genetic algorithm. This method can accurately detect location of any mesh modification [29].

Lin et.al also proposed a fragile watermarking technique in which local mesh parameterization approach is used to perturb the coordinates of invalid vertices, which can be used for localization of changes, and for region-based tampering detection [30].

A semi-fragile watermarking method for 3D models using integral invariants is proposed, robust against rigid transform and noise attacks [31].

Wu proposed a fragile 3D watermarking scheme wherein a sequence of data bits is adaptively embedded into the mesh model adjusting the vertex positions properly, and blindly extracting the bit information from the watermarked mesh model using a key [32].

Rakhi et.al proposed a new DRM system for 3D graphics that makes use of biometric watermarking technology in which an image of a biometric trait e.g. face or fingerprint is embedded into the 3D graphics as a watermark which is then used to authenticate a legitimate user [33].

Fan et.al developed a blind digital watermarking algorithm using depth perceptual region of interest (DP-ROI) for copyright protection of three dimensional (3D) images is proposed. The three-dimensional depth sensation of human visual system is utilized to define DP-ROI and it is then extracted through depth image and gray image. The gray image is transformed with discrete cosine transformation (DCT) to embed watermark into the several adjusted middle frequency DCT coefficients in DP-ROI. Finally watermark is extracted by computing the correlation of DCT middle frequency coefficients [34].

Zadokar et.al proposed a watermarking method for content protection using discrete wavelet transform (DWT) on anaglyph 3D images, where the embedded watermark can be efficiently extracted despite any noise attack on a front image [35].

4. CONCLUSION

This paper discusses the various existing 3D Watermarking techniques under the different headings on robust and fragile watermarking schemes. It also discusses the basic idea behind the robust and fragile watermarking system along with some of their various existing algorithms which will give a profound knowledge to others pursuing research in the concerned domain i.e.3D watermarking.

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