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A Robust and Blind 3D Mesh Watermarking Approach Based on Particle Swarm Optimization

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ABSTRACT

This article presents a robust 3D mesh watermarking approach, which adopts an optimization method of selecting watermark vertices for 3D mesh models. The proposed approach can enhance the imperceptibility of the watermarked model without affecting the robustness and capacity factors. The proposed watermark approach depends on an embedding algorithm that use a clustering strategy, based on K−means clustering algorithm in conjunction with the particle swarm optimization to divide the mesh model vertices into groups. Points of interest set (POIs) are selected from these clustered groups and mark it as watermark vertices where the (POIs) are invariant to most of the geometrical and connectivity attacks. Then, the proposed approach inserts the watermark bit stream in the decimal part of spherical coordinates for these selected watermark vertices. The experimental results confirm that the proposed approach proves its superiority compared with state-of-the-art techniques with respect to imperceptibility and robustness.

KEYWORDS

3D Mesh Model, K−Means, Particle Swarm Optimization (PSO), Point of Interest (POIs), Swarm Optimization, Watermark

1. INTRODUCTION

Nowadays, three-dimension data object became a part of our daily life applications. Such applications include: entertainment application like 3D movies and video gaming, engineering applications like engineering design, architectural walk through, business applications like e-commerce, and finally scientific applications like scientific visualization and virtual reality. Most of three-dimension data objects are represented by 3D triangular mesh with the plenty of true reflection of object topological structure (Kuo et al., 2009). Such huge amounts of 3D objects in different applications are being used by many people all over the time using the availability of large network bandwidth. Such data exchanging requires protecting data object through transmission against illegal usage (Hu et al., 2014). The Digital watermarking algorithm can be divided into basic two processes: The first one is the embedding process by adding copyright information into the original data object, while the other process is the extraction of such information. Such embedding and extraction processes must guarantee the detection of any modifications in the original data object. In order to evaluate the quality of watermark algorithm we should take consideration of three main requirements the capacity of

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the embedded watermark, model imperceptibility, and the robustness of the embedded watermark against different types of attacks (Medimegh et al., 2018). Each type of watermark algorithms has its own preference, and restrictions. There is always a tradeoff between watermark requirements. Trying to improve one requirement will reduce the effect of the other requirements. For example, improving watermark robustness will affect watermark imperceptibility and vice versa. Watermarking algorithms can be classified in different ways (Nikolaidis et al., 2001). They can be categorized based on watermark visibility.

Watermark can be visible or invisible in the input object. Watermark algorithms can also be classified based on their robustness into robust, fragile, and semi-fragile. Other classification criterion is related to the need of the original model during the extraction process. In non-blind watermark algorithms, original model during the extraction process is not used, while performing extraction having only watermarked model means a blind watermark approach is used. Finally, watermarking algorithms may be classified based on the embedding domain of watermark into the original cover object. The watermark is embedded either in the spatial domain or the transform domain. Most research work on watermark algorithms focused on traditional data object like text, image, and audio data. Recently researchers start to give attention to 3D object models. One of the first proposed works in the field of 3D watermarking was proposed by (Ohbachi et al., 1997). He proposed an embedding algorithm of 3D watermark in the spectral domain. The algorithm was robust against different types of attacks like similarity transform, smoothing, random noise addition, and simplification attacks. Recently there have been many publications that give attention to the problem of 3D model watermarking, and how to improve the watermark algorithms according to the basic main requirements.

Several slanders were proposed in literature to provide Points of Interest for mesh models (Novatnack and Nishino, 2007; Castellani et al., 2008; Sun et al., 2009; Sipiran and Bustos, 2011). The set Points of Interest that detected from the proposed technique using k-means and PSO clustering method with all these standers. Moreover, a comparison between this work by the previous work proposed in (Mourad et al., 2017) for point of interest selection using k-means clustering only. Also, another comparison between this proposed technique and state of the art methods used in watermark embedding and extraction (Cho et al., 2011 and Medimegh et al., 2018). The experimental results proved that, the effect of using an intelligent algorithm such as PSO in the selection of watermark carriers in terms of both model imperceptibility and watermark robustness against different types of attacks.

In this paper, a 3D mesh watermarking approach is proposed, it is considered as an optimization algorithm with the aim of achieving the best of watermark requirements. Bio-Inspired optimization techniques and artificial intelligence techniques such as genetic algorithm, differential evolution, particle swarm, Fuzzy logic, neural networks, etc. have been employed to solve different optimization problem. In this paper, we introduce a blind watermark approach, where there is not needed to have the whole mesh model during the extracting process. The objective of this proposed approach is to utilize an intelligent algorithm in the selection of vertices or POI that can be marked as good candidates to carry the watermark. These points are invariant and robust to various types of attacks like geometry and connectivity attacks. The proposed approach used K-means algorithm in combination with particle swarm optimization (PSO) to extract a set of interest points from the whole mesh model vertices. Such interest points are in the most prominent areas. Particle Swarm Optimization (PSO) is used to refine the clusters formed by K-means algorithm (Van der Merwe and Engelhrecht, 2003).

The remainder of this paper had arranged as follows. Section (2) explores some related papers that proposed in literature for 3D watermarking and presents some basic preliminaries. In section (3), the proposed watermark technique is presented in detail followed by the watermark robustness verification step while the experimental results were discussed in Section (4). Finally, Section (5) introduces the conclusion of the proposed approach.