3D Models of Oblique Photography Watermarking Algorithm

Subjects: Computer Science, Interdisciplinary Applications
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With the rapid development of oblique photogrammetry technology based on unmanned aerial vehicle (UAV), 3D models of oblique photography (3DMOP) are playing an increasingly significant role in the establishment of digital cities and twin watersheds, due to their huge advantages such as high accuracy, clear texture information, virtual simulation capability, etc. igital watermarking, an important branch of data hiding, has played an important role in security protection of digital products, such as digital images, CAD graphics, remote sensing images, vector maps, etc., and a huge amount of research results have been obtained.

Keywords: 3DMOP ; watermarking ; algorithm ; 3D mesh ; 3D point cloud

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1. Introduction

With the rapid development of oblique photogrammetry technology based on unmanned aerial vehicle (UAV), 3D models of oblique photography (3DMOP) are playing an increasingly significant role in the establishment of digital cities [1][2] and twin watersheds [3], due to their huge advantages such as high accuracy, clear texture information, virtual simulation capability, etc. Despite their significant utility, the security issues they face are becoming increasingly prominent [4]. Compared with other types of spatial data, 3DMOP have higher positioning accuracies of clearer texture information, in which classified elements (e.g., prisons and barracks) can be accurately located and sensitive information (e.g., car numbers and human portraits) may be exposed thoroughly [5]. When a leakage of this classified or sensitive information occurs, irreparable losses will be caused to data sharing, commercial interests, and even national security. Against this background, it is particularly important to take effective protective measures to prevent data theft and illegal dissemination. Digital watermarking [6] and data encryption [7], two representative technologies of data security protection, have been considered as effective means for security protection of 3DMOP [8].

Digital watermarking, an important branch of data hiding, has played an important role in security protection of digital products, such as digital images [9][10], CAD graphics [11][12], remote sensing images [13][14], vector maps [15][16], etc., and a huge amount of research results have been obtained. However, few works have been carried out focusing on the security protection of 3DMOP.

While 3DMOP have played an important role in various fields, they are facing significant security issues. Traditional security protection methods of 3DMOP still have limitations, especially in the security protection of secret information in texture images.

As a professional application of digital watermarking, 3DMOP's watermarking technology has become a research hotspot in recent years. According to the embedding location of the watermark, traditional research can be divided into two categories, i.e., algorithms based on 3D meshes [17][18][19][20][21][22] and 3D point clouds [23][24][25][26][27][28].

2. 3DMOP Watermarking Algorithm Based on 3D Mesh

The 3DMOP watermark algorithm based on a grid embeds the watermarks into the grid features. Zhou et al. (2007) proposed a robust digital watermarking algorithm for 3D mesh models based on wavelet transform [17], and Xing et al. (2009) proposed a 3D model digital watermarking algorithm based on DWT (discrete wavelet transform) and SVD [18]. The above two types of watermarking algorithms are robust against cropping and noise attacks but cannot resist translation and rotation attacks common in the application of 3DMOP. Soliman et al. (2015) used genetic algorithms to embed watermarks into selected points after K-means clustering, and the algorithm has strong robustness, but it is a non-blind watermarking algorithm and has poor practicality [19]. Zhan et al. (2014) proposed a robust watermarking algorithm for 3D mesh models based on vertex curvature, which uses the root mean square curvature of vertices for watermark embedding

[20]. Zhang et al. (2014) extracted significant regions in 3D models, converted them to spherical coordinates, and performed wavelet transform to embed watermarks into low-frequency and high-frequency regions [21]. Algorithms in [20] [21] have good robustness against translation, rotation, noise attacks, etc. Zhu et al. (2014) proposed a digital watermarking algorithm for 3D mesh models based on roughness [22], which selects candidate vertices through the normal vector and the angle between the weighted normal vector of the local geometric space closure-ring neighborhood. It can effectively resist simplification attacks, but the above three algorithms are not robust against cropping attacks.

3. 3DMOP Watermarking Algorithm Based on 3D Point Cloud

The 3DMOP watermark algorithm based on point clouds embeds watermarks by modifying the coordinates of the 3D point cloud. Wang et al. (2009) modified the integral invariants of some vertices by shifting the vertices at the vertex and its adjacent positions to embed the watermarking [23]. However, this algorithm is a semi-fragile watermarking, which can usually be used for data integrity authentication, but cannot be used for copyright protection of 3D models. Wu et al. (2012) selected the one-dimensional DWT low-frequency signal of the distance between each point in the point cloud model and the center of gravity of the model to embed watermarking [24], which is robust to cropping attacks, but less robust to common rotation and translation attacks. Feng et al. (2016) proposed a 3D point cloud algorithm based on angle quantization exponential modulation [25], which is robust to affine transformation, reordering, low-intensity noise, etc. Shang et al. (2015) transferred the 3D model from a rectangular coordinate system to a spherical coordinate system [26] and used the distance from the vertex to the centroid as the embedding object to complete the watermark embedding, which is robust to some affine attacks. The above two algorithms are robust to translation and rotation attacks, but not robust to cropping attacks. Wang et al. (2018) proposed a 3D model blind watermarking algorithm based on distance mapping mechanism [27], which is robust to common attacks such as translation, cropping, and rotation, but the effect is poor under simplification and noise attacks. Gong et al. embedded watermarking based on the characteristic line ratio of the 3D model, and the algorithm is robust to geometric attacks and noise, but the effect is poor for cropping attacks [28]. In summary, there are still deficiencies in the robustness and applicability of 3D model digital watermarking algorithms.

In the past, research on oblique photography 3D models focused more on embedding copyright information and the loss of model accuracy during watermark embedding. When embedding watermarks, more attention is paid to embedding watermarks in model vertex coordinate data and model texture data, with less research on embedding watermarks in texture coordinate data [29][30]; at the same time, the security of texture information is also neglected. 3DMOP, a special type of geospatial data, have different characteristics with other types of spatial data. In these different characteristics, the most special one is real texture information. A lot of secret information, e.g., advertising boards, car numbers and human portraits, can be conveniently viewed by users, including illegal users. This threatens the security of 3DMOP greatly. However, traditional security protection methods of 3DMOP generally ignored this point. Accordingly, there is still much space for security improvement of 3DMOP.

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