Digital Watermarking Using Group Quantization for CityGML Objects

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Abstract— In this paper, we proposed a watermarking method using group quantization for CityGML**.** We used the watermarking method using group quantization and the distribution of position of coordinates in consideration of the CityGML structural characteristics. By sorting the position of the coordinates, this method is robust against noise attacks and the invisibility is high.

Keywords— digital watermarking; group quantization; CityGML; geographic information system

I. Introduction

Recently, due to the development of network technology and the spread of personal computers as a multimedia system, the problem of illegal distribution has emerged as a social issue. However, unauthorized copying and distribution of digital content is a serious threat to the rights of content owners in many industries. In addition, copyright protection technology is required to prevent this phenomenon as people's perception of copyright increases dramatically. As a result, watermarking technology has been proposed for copyright protection and digital media authentication [1-4]. With development of Virtual Reality (VR) technology and Augmented Reality (AR) technology [5], interest in 3D models has increased more than ever. With the advent of 3D printing [6], digital twinning, and 3D geographic information systems [7], there is a growing demand for copyright protection for these 3D models.

With the development of architectural technology, the city has transformed into a forest of buildings, and the emergence of autonomous vehicles has increased the importance of spatial information about cities. The CityGML (City Geography Markup Language) [8] proposed by the Open Geospatial Consortium (OGC) is a method for expressing various LOD (Level of Details) as a standard spatial information representation method. CityGML is a common information model for the representation of 3D city objects. Define classes and relationships for the most relevant terrain objects in urban and regional models with respect to geometric, topological, semantic, and cosmetic attributes. Includes a generalization hierarchy between subject classes, aggregations, relationships between objects, and spatial characteristics.

The copyright protection of geo-spatial content created by CityGML is becoming more important because of the increased use of geospatial content. In particular, 3D geospatial information requires enormous production costs and technical measures to protect the rights of producers are very important. In this paper, we propose a digital watermarking technique using group quantization.

II. Related Works

A. Digital Watermarking

The concept of digital watermarking consists of hiding information in an inconspicuous digital content. This watermarked signal must withstand the most common signal processing primitives and even malicious attacks [5]. Hidden information is essentially tied to digital content and protected when encryption is lost. Digital watermarking does not replace encryption. They are two complementary technologies. On the other hand, encryption prevents unauthorized users from accessing digital content during transmission. Digital watermarking, on the other hand, leaves hidden evidence that is invisible to digital content when the user begins to illegally use the digital data to access and replicate or change content after decryption. If the content is misused, the copyright owner can find out who is responsible.

There are several schemes to hide information as a watermark. The method of self-correlation was proposed to be robust against RST attacks [16]. The holograms were generated from watermark information, and overwritten on the original images using a Fourier transform to facilitate their embedding. A watermarking algorithm based on a discrete fractional random transform (DFRNT) has been reported [17]; this algorithm exploits the inherent randomness of the transform itself. Generally, intrinsic randomness improves the watermark's robustness against attacks.

B. Digital Watermarking for 3D models

Most of the watermarking methods in 3D models are the target geometry of the 3D polygon mesh, and some are based on vertices, curves, surfaces, and mesh spectra.

In Ohbuchi [10] proposed method, they embedded the watermark into a 3D polygonal mesh in the mesh's spectral domain. The mesh spectrum is computed from the eigenvalue decomposition of the Laplacian matrix using mesh connectivity. This method is strong against general geometric transformation attacks. This method requires a lot of computation cost and is not a visual impairment. Yu [11] proposed algorithm is embedded the watermark by disturbing the length of the vector extending from the surface vertex to the center of the model. Watermarking strength is adaptive to the local geometry of the model and can be applied to models with a relatively small number of meshes. This method can withstand simplification and destroying crop attacks. However, the original model for watermark extraction is also required. Uccheddu [12] used a wavelet-based blind watermarking of 3D model. First, the PCA is used to normalize the model mesh, and then the watermark is inserted by disturbing the wavelet coefficients according to the value of the indexed watermarking map with the polar coordinates of the wavelet coefficient application point. High-resolution polygons are decomposed into low-resolution and detail parts, while details are represented by wavelet coefficient vectors. Model meshes are designed with semi-rule meshes and can be exploded by applying wavelet ideas. However, this operation cannot be applied to the CityGML model. Abdallah [13] The proposed method is not blind, but the work puts the watermark in a small sub-mesh. A 16-bit watermark was inserted into this operation, revealing complete resilience to cropping and smoothing attacks. Huang [14] and Wang [15] proposed fragile watermarking techniques for 3D models using spherical coordinates and Hamming codes, respectively. They both protect the integrity of the 3D model and prevent the problem of embedding holes.

III. Proposed Algorithm

Unlike 3D mesh model, objects included in CityGML have few vertices and are composed of various polygons as well as triangular meshes. As shown in Fig.1, CityGML objects have many rectangular.

The change of the vertex of CityGML is more sensitive than the change of the vertex of 3D model. Also, since CityGML uses geographic information, there is a restriction that the original geometry and topology should be kept as much as possible when inserting the watermark. In particular, objects such as buildings often have difficulty in inserting watermark information because there are many polygons that need to maintain flatness, such as walls or roofs.

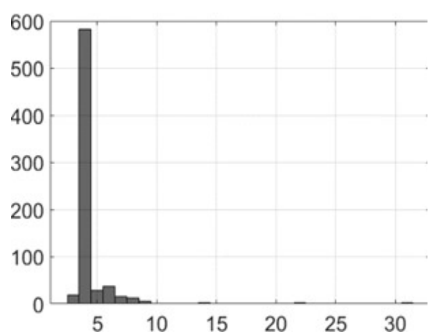

Fig. 1. Distribution of the polygons for CityGML object

A. Watermark Embedding Process

The proposed watermark embedding process is comprised of the below steps.

Step1: Extract the vertices from CityGML file and reconstruct the point cloud model. The set of unique vertices of the object is expressed as

$$V = \{v_i \in R^3 | 0 \leq i \leq N_v - 1\} \quad (1)$$

N_v is the number of vertices. Vertex v_i represents the coordinates in CityGML coordinates.

$$v_i = (x_i, y_i, z_i) \quad (2)$$

Step2: Select the proper coordinate for embedding watermark. The candidate coordinate should have tolerance for group quantization. The segmentation width is as below;

$$\mathrm{k} = \left\lceil \frac{\max x - \min}{n} \right\rceil \quad (3)$$

Step3: Choose segments and quantize the vertices. Group quantization segments vertices into similar ranges of values and quantizes the values of vertices composed of groups into Δ based on the median of the segment, thus the variations represent information of 1 and 0.

B. Watermark Extracting Process

The watermark extracting process has same process to Step2.

Step3: Calculate the mean of each segment then compare it to the center value of the segment. If the mean is greater equal than the center value the watermark is 1 and in the opposite case, it is 0.

IV. Experimental Results

A. Evaluation method

The Vertex Signal-to-noise Ratio (VSNR) [15] is used to determine the perceptual variations between the original and watermarked models. Where Nv is the number of all unique vertex, (X_j, Y_j, Z_j) and (X_j*, Y_j*, Z_j*) are the original and altered Cartesian coordinates of the vertices.

$$SNR = \frac{\sum_{j=1}^{Nv} X_j^2 + Y_j^2 + Z_j^2}{\sum_{j=1}^{Nv}\left[\left(X_j - X_j^*\right)^2 + \left(Y_j - Y_j^*\right)^2 + \left(Z_j - Z_j^*\right)^2\right]} \quad (4)$$

$$VSNR = 10\log_{10}(SNR) \quad (5)$$

The correlation coefficient [16] Cor is used to estimate the robustness of the method. Where Wm' and Wm are the extracted watermark and original watermark, respectively. Nw is the length of the watermark, $\overline{Wm'}$ and $\overline{Wm}$ are the mean value of Wm' and Wm, respectively.

$$Cor(Wm', Wm) = \frac{\sum_{i=1}^{Nw}(Wm_i' - \overline{Wm'})(Wm_i - \overline{Wm})}{\sqrt{\sum_{i=1}^{Nw}(Wm_i' - \overline{Wm'})^2 \sum_{i=1}^{Nv}(Wm_i - \overline{Wm})^2}} \quad (6)$$

B. Experimental results

We conduct experiments on an object in a CityGML model. The build object has 1083 and 2138 vertices and 711 and 1318 faces. The visualized Objects are shown in Fig. 2.

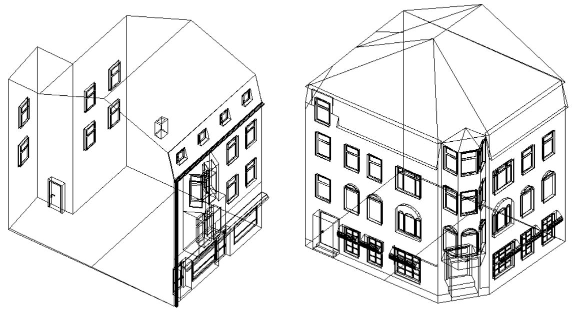

Fig. 2. CityGML objects for experiment

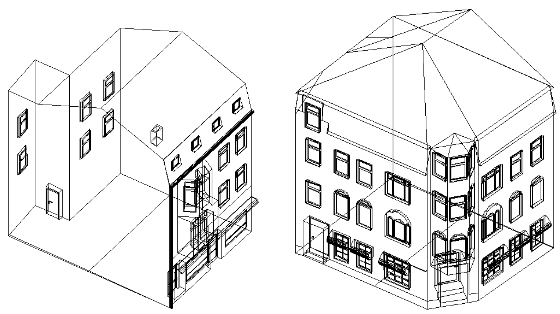

Fig. 3. Watermarked CityGML objects

The VSNRs of the objects are 170.37[dB] and 170.41[dB] respectively.

The capacity of watermark embedding depends on the quantization range. Experimentally, it is possible to insert a watermark between 32 bits and 64 bits in a building. Our proposed algorithm is robust against Gaussian noise attack. The mean of the distribution are all 0. Table 1 shows the watermark extraction BER (bit error rate) results based on standard deviation values. Increasing the quantization range can increase the insertion strength. If the quantization range is larger, this algorithm is more robust against noise attack.

TABLE I. WATERMARK EXTRACTION RESULT BY ATTACK

64 bit	VSNR(dB)	BER(%)	Add Noise BER(%)				
			0.001	0.002	0.003	0.004	0.005
BD1	170.37	0	0	0	9.3	18.7	39
BD2	170.41	0	0	0	0	12.5	37.5
BD3	167.82	0	0	0	6.2	6.2	31.2
BD4	170.34	0	0	0	3.1	21.8	18.7
BD5	168.38	0	0	0	0	12.5	28.1

V. CONCLUSIONS

In this paper, we proposed a blind watermarking method using group quantization for CityGML models. We used the watermarking method using group quantization segments vertices into similar ranges of values and quantizes the values of vertices in consideration of the CityGML structural characteristics. By sorting the position of the coordinates, this method is robust against noise attacks and the invisibility is high.

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