A Novel Data Hiding Algorithm Using Normal Vectors of 3D Model

Chung-Hsien Chang, Chung-Ming Wang, Yuan-Yu Tsai, and Yu-Ming Cheng

Institute of Computer Science, National Chung Hsing University, Taichung, Taiwan
{cschang, cmwang, cuckoo, s9156048}@cs.nchu.edu.tw

Abstract. This paper presents a novel data hiding algorithm for 3D polygonal models whose vertices have given normal vectors. The key idea of our algorithm is to embed messages by adjusting the normal vector of a vertex according to the pivot vector. All vertices in a 3D model can be embedded with multiple-bit payloads by using multiple pivot vectors. The distortion is measured by the angle between the adjusted normal vector and the original normal vector to distortion. A distortion coefficient is also introduced to control the distortion rate during the embedding process. Experimental results demonstrate that our algorithm can achieve high data capacity (up to 12 bits per normal vector), and is robust against rotation, translation, and uniform scaling attacks.

1 Introduction

Data hiding is embedding data in other harmless messages and does not allow anyone, except those with the secret key, to detect the secret message. Data hiding [5, 8] usually uses digital multimedia data, such as movies, music, and images, as cover media to embed hidden information. Preferred data hiding algorithms embed as much data as possible and form the stego model with as little distortion as possible. There are different representations used for three-dimensional (3D) models. A 3D model can be described as a set of parametric curves or a collection of defining functions. For example, the equation $x^2+y^2+z^2=1$ describes a sphere with a unit radius in 3D space. More commonly, polygonal meshes are used to represent a 3D model. The normal vector assigned at a vertex is generated automatically in the shading process. Sometimes, to describe the curvature of a surface more precisely, given normal vectors will be associated with vertices. Thus, a vertex in 3D model can be defined as a set of six floating point numbers. For example, $(x, y, z, P_x, P_y, P_z)$ where $(x, y, z)$ is the position of the vertex and $(N_x, N_y, N_z)$ is the normal of the vertex. Recently, many data hiding and watermarking algorithms have been presented for 3D models. Most of them support polygonal models [1, 2, 3, 6, 7, 11] while a few of them are for point-sampled geometries [4, 10]. Although embedding data into the topology and geometry of models has been explored extensively, its counterpart for normal vectors has not been explored as much as it deserves.

In this paper, we propose a new data hiding technique for 3D models whose vertices have given normal vectors. For each vertex, we embed a payload by adjusting the direction of its normal vector. We use one or multiple pivot vectors as keys for
embedding and extracting data. The angle between a pivot vector and normal vector is used to determine embedded information. The more pivot vectors are involved, the more payloads we can embed. This scheme allows our method to achieve a huge capacity for data hiding. In our algorithm, we leave the position information untainted. Therefore, our method is robust against rotation, uniform scaling, and translation attack.

This paper is organized as follows: section 2 discusses related works. The proposed algorithm including the information embedding process and extracting process is presented in section 3. Section 4 shows experimental results using several models. Conclusions and future work are described in the final section.

2 Related Work

Many watermarking and data hiding techniques have been proposed on 3D models. Aspert et al.[1] proposed an approach which transformed Wagner’s watermarking technique[11] into a data hiding algorithm for 3D polygonal meshes. They use small displacements of the vertices in the model to embed the information. Recently, Maret and Ebrahimi[6] made some improvements to [1, 11] by increasing the embedding capacity and reducing the complexity of data extraction. They increased the capacity by adapting the embedding process to the sample distribution in the similarity-transform invariant space. They reduced the complexity of message extraction by making use of a similarity invariant space.

Cayre and Macq[3] described an algorithm for 3D polygonal models in the spatial domain. The message was embedded within the model topology and the key idea was to consider a triangle as a two–state geometrical object. They established a list of admissible triangles from the cover model. The position of a vertex in each admissible triangle was changed or not, according to the embedding bits. Wang and Cheng[9] presented a more efficient approach. They considered every vertex of a triangle as a message vertex and adopted a triangle neighbor table and an advanced jump strategy to assign embedding order to the message vertex quickly. They also defined a metric of distortion evaluation which helped them forecast and control the distortion rate.

Cotting et al.[4] presented a watermarking approach for point-sampled geometry. They embedded watermarks into the low frequency components, and employed statistical methods based on correlation to analyze the extracted watermarks. Wang and Wang[10] proposed two data hiding approaches for point-sampled models. They established a list of intervals for each axis according to the secret key, and embedded a bit into each interval by changing the points’ position. They also used a list of macro embedding primitives to achieve higher data capacity.

Most of the abovementioned works presented for data hiding or watermarking are based on the topology and geometry of models. We propose a novel data hiding algorithm that exploits the feature of those 3D models which have given normal vectors. This algorithm provides a huge capacity and resists rotation, translation, and uniform scaling attacks.