

# GEOMARK

## Watermarking of 3D models

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### Digital Watermarking

During the last decade, research in digital watermarking for multimedia data has mainly focused on still images, video and audio streams.

Recent years have shown considerable progress in the field of watermarking algorithms for geometric 3D data. Copyright owners are facing the problem of protecting their intellectual property rights. On the other hand customers want to be sure the 3D content is indeed well-formed and its use is authorized by the copyright owner.

Digital watermarking helps to fulfill the copyright owners' as well as the customers' needs. The content can be safeguarded against unauthorized or unlicensed use. A secret watermark introduces the licensee's identity into the data itself, enabling the copyright owner to trace back the origin of illegal copies. For embedding and retrieval of the watermark information at least one secret key is needed, known only to the copyright owner or a trusted clearing centre.

A second, public watermark can be retrieved by the customer to authenticate the 3D model, so the customer is able to verify that the data has not been tampered with. The added value of watermarks for authentication – as compared to cryptographic methods – is that specific operations that do not affect the integrity of the model, such as rotation or translation, do not break the authentication mechanism.

Public watermarks can also be used to provide additional convenience information, e.g. for indexing purposes in large model databases.

### Robustness

Private watermarks should be resistant against processing that does not substantially degrade the visual quality of the 3D model. Besides polygon

simplification, which is commonly used to achieve higher rendering speed for 3D scenes, possible operations are rotation, translation and scaling of the model. Other operations may apply local or global deformations to the data or remove parts of the model. Moreover, the watermark should ideally survive a digital to analog conversion, i.e. making a hard copy of the model and subsequent scanning to transform the model back to the digital representation.

GEOMARK is a family of algorithms for embedding secret and public watermarks into 3D models or compositions of scenes containing these models in addition to texture and audio elements. Depending on the application scenario, different algorithms can be used.

Public watermarks:

- Vertex-Flood-Algorithm (VFA)
- Affine Invariant Embedding (AIE)

Private watermarks:

- Normal Bin Encoding (NBE)
- Free Form Deformation (FFD) based Embedding

### German Abstract

GEOMARK ist ein System, das digitale Wasserzeichen für dreidimensionale Datensätze realisiert. In Abhängigkeit vom Anwendungsszenario kommen unterschiedliche Algorithmen zur Anwendung. Beispiele für Einsatzgebiete sind robuste Wasserzeichen für den Urheberrechtsschutz oder die Authentifizierung von Modellen. Das Wasserzeichen im Modell bleibt unabhängig vom Dateiformat erhalten und ist robust gegen verschiedenste alltägliche Verarbeitungsoperationen.

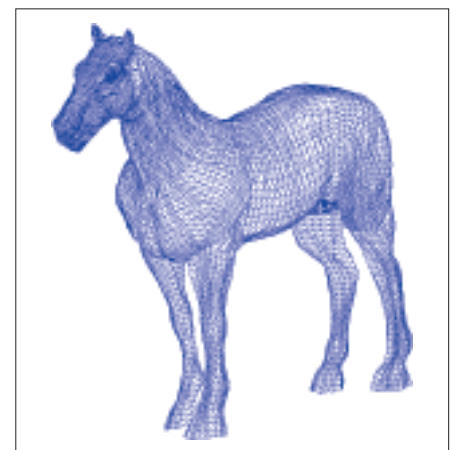


Figure 1: Model consisting of 22258 triangles

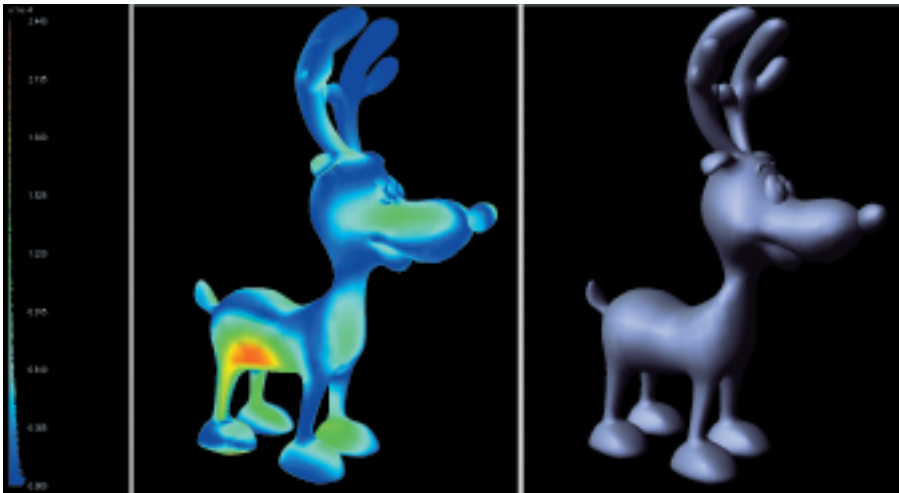


Figure 2: Left: Visualization of differences between original and model watermarked using the FFD-based algorithm. Right: Original model

GEOMARK algorithms are suitable for embedding public and private watermarks in polygon-based 3D models. The private watermarks embedded using the FFD-based algorithm show robustness against

- translation,
- scaling,
- polygon simplification and reduction,
- re-meshing operations,
- introduction of noise, and
- removal of faces.

None of the algorithms changes the connectivity of the model, only the geometry is modified by the watermarking process.

### Private Watermarks with GEOMARK

The Normal Bin Encoding (NBE) algorithm is capable of embedding private watermarks in 3D geometric data. The NBE watermark does not alter the visual quality of a 3D model and is robust against randomization of points, mesh altering (re-meshing) operations and polygon simplification. The FFD-based algorithm is able to embed a watermark that even survives the digital-analog-digital conversion process: After making a hard copy of the watermarked digital model and re-digitalization of the copy using a laser scanner, the watermark can be retrieved from the reconstructed digital model.

The basic idea of the NBE algorithm is that a 3D object may be considered as a collection of surfaces of arbitrary size and orientation. A near to infinite number of meshes may represent or approximate that particular set of surfaces with varying degree of perceived quality. NBE uses a collection of surface normals as embedding primitive. Thus a modified representation of the 3D object will not affect the watermark if the new vertex face set configuration maintains size, orientation and curvature of the surface.

NBE is available as blind detection scheme that does rely only on the watermarked 3D model to retrieve the watermark information. This algorithm implements a one-bit watermark which is tailored for applications that focus on ownership proving.

The FFD-based algorithm uses slight free form deformations of the model to embed a one-bit watermark. The algorithm makes use of the original model during watermark retrieval, thus representing an informed detection scheme. Due to its registering and pre-processing stage the FFD-based algorithm is robust against affine transformations in combination with polygon simplification.

### Public Watermarks with GEOMARK

The Vertex Flood Algorithm (VFA) and Affine Invariant Embedding (AIE) have been developed to embed high-

capacity public watermarks in 3D data sets.

Both algorithms encode the watermark within information about the distance between vertices. AIE uses a more sophisticated scheme than VFA, thus providing robustness against affine transformations, whereas VFA provides a higher capacity than AIE.

Typically, VFA is able to embed several thousands of bits into a model consisting of some ten thousand vertices, while AIE is capable of embedding several hundreds of bits into the same model.

Moreover, VFA can be used to embed a fragile watermark, which is destroyed as soon as alterations of the model exceed a predefined threshold. In conjunction with encryption techniques like digital signatures and hash values, fragile watermarks can be used to authenticate a 3D data set.

### Conclusions

With GEOMARK, watermarking technology enters the Computer Graphics domain, establishing methods for protecting copyrighted polygonal 3D model data.

Depending on the application scenario, GEOMARK implements different algorithms for copyright protection, model authentication, embedding of licensing or any other useful additional information independently of the file format used.

It should be noted that it is possible to mix watermarks embedded with different GEOMARK algorithms within the same 3D model. By stacking NBE, AIE and VFA, we achieve labeling in combination with model authentication and watermarks resistant either to affine transformations or polygon reduction.

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