

Watermarking of Audio, Music Scores and 3D Models

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Abstract

The incessant increase of hardware and network capacities together with the improvements of software and compressing algorithms like MPEG 1 Layer III, generates a rapidly growing market for handling audio data. An easier distribution and reduced storage requirements lead to the negative effect of an uncontrolled spreading of copyrighted audio material.

Easy-to-use peer-to-peer services are currently used to exchange the locally stored data of participating clients. As a result, illegal copying and distribution of music via the Internet must be considered a new form of piracy. It was made possible primarily due to the reduced size of the digital audio data and the increased bandwidth available to both consumers and organized crime. New technologies are necessary to incorporate protection of intellectual property rights. A©WA, WoMuS and GeoMark embed watermarks into audio, music scores and 3D models respectively to provide means of protecting owners' and authors' intellectual property rights.

A©WA – Audio ©opyright Protection by Watermarking

A©WA, a tool for embedding watermarks in digital audio data, is based on a statistical method and an underlying psychoacoustic model to embed a transparent and robust watermark into WAVE files. Using A©WA, two watermarks can be simultaneously embedded without interfering with one another. The default data rate of 8 bits/second can be adjusted according to the requirements regarding robustness and the minimum data size of the audio file. The authorization of reading the watermark is driven by using a key.

The A©WA embedded watermark is robust among other things against

- MPEG 1 Layer 3 compression down to 128kBit/s
- EQ +/- 6dB
- Sample rate conversion (44.1 22.05 kHz)
- Stereo-Mono conversion
- Format conversion

German Abstract

Die zunehmende Verfügbarkeit und der Vertrieb von multimedialen Daten über das WorldWide-Web bedingt auch die Frage nach einer Absicherung der Urheberrechte an multimedialen Daten. Dies insbesondere vor dem Hintergrund, daß durch die digitale Repräsentation von persönlichen geistigen Schöpfungen im Sinne des Urhebergesetzes (UrhG) Original und Kopie eines multimedialen Werkes (Bild, Video, Audio etc.) nicht unterscheidbar sind. Kopien können mit geringem Aufwand erstellt werden und die Weiterverarbeitung und Manipulation der Daten ist nur mit geringem Aufwand verbunden. Als technische Massnahme zum Schutz des Urheberrechtes bietet das Verfahren der Digitalen Wasserzeichen Abhilfe, das eine nicht detektierbare und robuste Kennzeichnung digitaler Daten ermöglicht mit dessen Hilfe ein Missbrauch urheberrechtlich geschützter Daten aufgedeckt werden kann. Die verschiedenen Anforderungen wie die Erhaltung der Qualität der markierten Daten und die Robustheit der eingebetteten Wasserzeichen erfordern die Entwicklung von unterschiedlichen Algorithmen für die Markierung unterschiedlicher Datentypen.



Figure 1: A©WA VST-Plugin

A©WA is available as batch oriented command line version and library for the Windows platform. The software can be easily adjusted to the user's needs regarding the balance between robustness, inaudibility and the payload size of the watermark. Furthermore, A©WA is implemented as a VST-PlugIn (see Figure 1) under Microsoft Windows 98 and Windows 2000. The PlugIn has several advantages. Because of the widespread distribution of the VST technology, this audio watermarking method can be applied in a variety of sound processing tools. Moreover, the integration as a PlugIn enables an easy evaluation and adjustment of both the quality of the watermarked audio tracks and the robustness of the embedded watermarks. The Demo version of the VST-PlugIn is free for non-commercial use. For downloading the VST_PlugIn visit the Web-site: <http://syscop.igd.fhg.de/AcwaVSTPlugIn.htm>.

A©WA – Hardware Solution

A©WA exists as a hardware solution to embed watermarks in streaming audio. The hardware solution uses the same framework as the software solution. In addition it uses the ASIO-Interface. This makes it possible to use it with any standard sound card that supports ASIO. Of course, this version of A©WA supports FileIO as well. Benefits of the hardware based solution are:

- realtime watermarking
- different combinations of input/output types (streaming and/or FileIO)
- any soundcard supporting the ASIO interface is ready to use in A©WA

Application Scenarios

Besides selling hardcopies of audio tracks in form of CDs, the broadcasting of audio streams over the air or the distribution of audio files over the internet offer interesting applications for watermarking systems:

- broadcast monitoring: in this case the watermark is used for identification purposes of the broadcaster and track.
- copyright protection: for copyright protection applications, the copyright owner is iden-

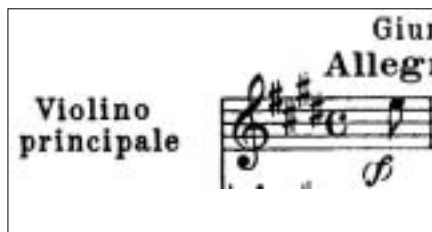


Figure 2: binary method with staff lines as information carrier: original image (300dpi, binarized) in comparison to watermarked image



Figure 3: musical symbols as information carrier – original image in comparison to watermarked image: distance between notes and width of note heads are used as information carrier



Figure 4: geometrical line properties are used as information carrier: curvature and vertical distances are changed

- annotation watermarking: to provide users with public information within a streaming audio transmission, the watermark technologies can be used to embed the information as a public watermark.

WoMus – Watermarking Of Music Scores

Various approaches are being developed which differ from each other in the way of how information is embedded in a music score. Therefore, these methods have different properties concerning quality, capacity and robustness. Depending on the requirements a user has to choose a watermarking scheme which fits his needs best.

Content independent data hiding

Our first solution of hiding data is to use image watermarking techniques. Unfortunately, these techniques have one major drawback: They are embedding a watermark in the frequency domain. Greyscale to binary conversion will remove this kind of watermark without losing musical content. Therefore methods developed for binary images have to be used. We applied a watermarking method for binary images, which was developed at our department. Quality improvement was possible by restricting this technique to certain musical symbols. Horizontal structures, like staff lines, bar or slurs, have been identified as good information carriers (figure 1).

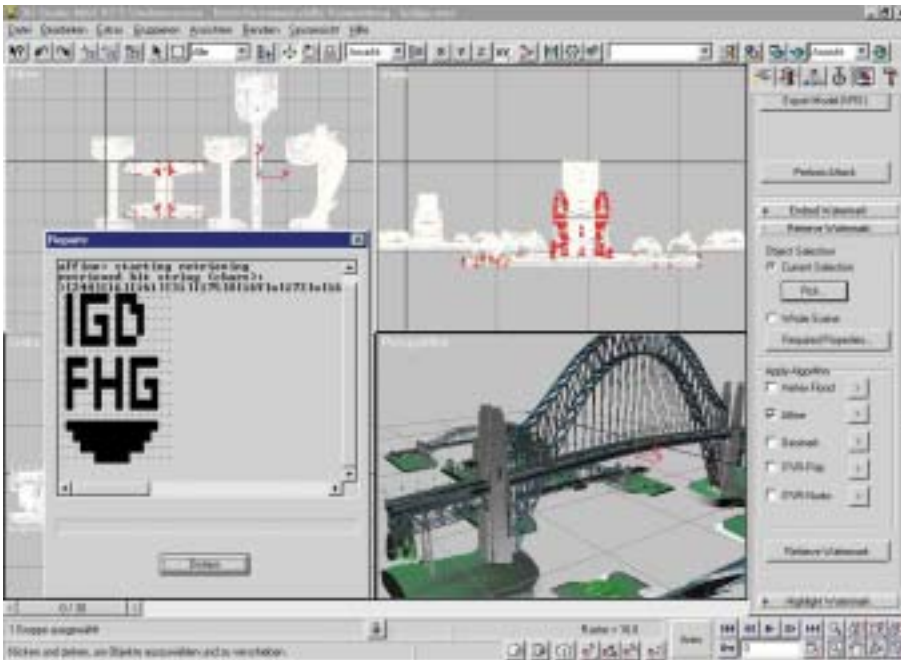


Figure 5: Retrieving a watermark (bitmap from affine transformed models)

Watermarking Regarding the Content

By limiting binary watermarking techniques to certain musical symbols, the content is regarded. But instead of changing some pixels of certain symbols, a more interesting approach is to consider the features provided by musical symbols directly.

- musical symbols as information carrier
Considering the musical symbols, the horizontal distances between them and the width are suited features for an information carrier. In this approach the capacity, i.e. the amount of information which can be hidden, depends on the number of symbols in the music score (figure 2).
- staff lines as information carrier
Using the properties of the staff lines for hiding information allows the designing of a method whose capacity is independent of the number of musical symbols. We use the geometry and the horizontal distance for hiding information (figure 3).

GEOMARK – Watermarking of 3D Models

The goal of the Geomark-System is to supply watermarking technology for labeling- and copyright-related applications (tracing of illegal copies, proof of ownership) for 3D content in the application fields of modeling, animation and visualization. Models in digital as well as in physical representation (e.g. 3D plots of design prototypes) are addressed.

The possibility of labeling 3D content, models and virtual scenes, allows the following general applications:

- provide users of 3D data with links to the origin of the model or related information, e.g. associated textures.
- embed information supporting the visualization process of a model or scene.
- support the workflow in collaborative environments through embedding of history-related information.
- models or scenes can be checked for completeness or for modifications by embedding.
- support automated indexing of models in databases by embedding (symbolic) classification-information.

The Geomark-system is realized as a 3D Studio MAX-plugin and offers in its current version the following functionality:

- labeling, integrity check and authentication of polygonal 3D models through public readable fragile watermarks (we call these watermarks fragile).
- local secret and public readable watermarks for polygonal models and NURBS control nets surviving affine transformations (we call these watermarks semi-robust).
- secret watermarks robust to more complex transformations, e.g. free form deformation, and polygon-reduction for the purpose of tracing copies (we call these watermarks robust).

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