Study of Digital Watermarking for Multimedia

A project submitted in partial fulfillment of the requirements for the Multimedia Communications Course

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Contents

Description of the Problem:

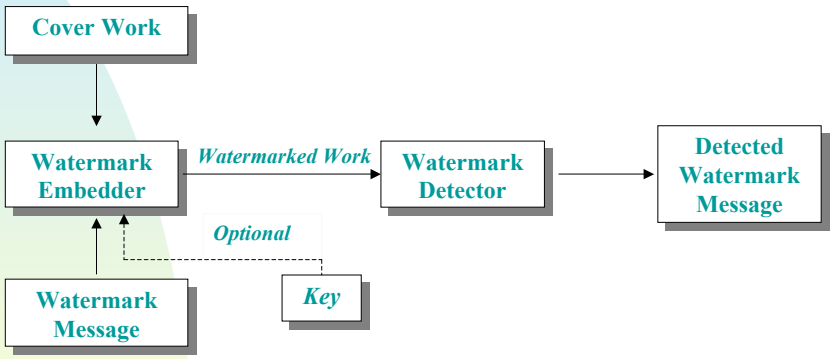
- **What is Digital Watermarking?**

  Digital watermarking technology allows users to embed data into digital contents such as text, still images, video and audio data.

- **Purpose of Watermarking:**
  - **Copyright Protection**
  - **Fingerprinting**
  - **Copy Protection**
  - **Broadcasting Monitoring**
  - **Data Authentication**

Description of the Problem:

Terminology. Generic Watermarking Scheme



Types of Watermarks

- **Perceptibility**
  - visible/audible
  - invisible/inaudible
- **Robustness**
  - fragile
  - semi-fragile
  - Robust
- **Necessary Data for Extraction**
  - blind
  - informed
- **Inserted media**
  - text
  - audio
  - Video
- **Inserting Watermark Type**
  - noise
  - Image
- **Processing Method**
  - spatial
  - spectral

Limitations

- **Image processing operations**
  - filtering, dithering, cropping, scaling, compression
- **Attacks**
  - Robustness attack
  - Presentation attack
  - Interpretation attack
  - Legal attack

Digital Watermarking Properties

- **Properties related to the embedding process**
  - **Embedded Effectiveness**
  - **Fidelity**
  - **Data Payload**
- **Properties related to the detection process**
  - **Blind/Informed Detection**
  - **False Positive Rate**
  - **Robustness**
- **Properties related to both embedding and detection**
  - **Security**
  - **Cost**

Digital Watermarking Techniques

- Text-based Watermarking
- Image Watermarking
- Audio Watermarking
- Video Watermarking
- 3D Watermarking

Text-Based Watermarking

- Uses
  - protect electronic documents
  - paper documents are easy to copy and distribute electronically (scanning, OCR)
- Challenges
  - marking copies uniquely
  - making necessary for a recipient to provide personal information
  - using encryption

Text-Based Watermarking Techniques.

- Open space methods
  - inter-sentence spacing
  - end-of-line spaces
  - inter-word spacing
- Syntactic Methods
- Semantic Methods

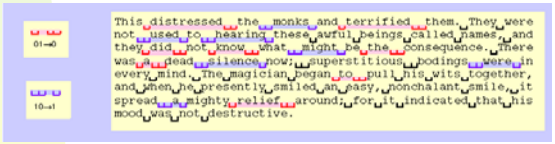


Image Watermarking Techniques

- Least Significant Bit
- Correlation-Based Techniques
- Frequency Domain Techniques
- Wavelet Watermarking Techniques
- Spread Spectrum Techniques

Least Significant Bit

without watermark

with watermark

Correlation-Based Techniques

Watermark Detected

>T

Gain Factor

Correlator

Thresholding

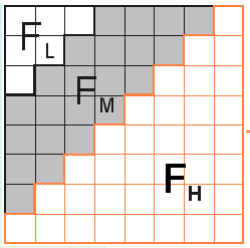
Secret Key

< T

Random Noise Generator

Watermark not Detected

Frequency-Based Techniques



DCT Coefficients

Random Pattern generated using a secret key

4 16 4 4 36 0 1 0 16 …….. 1 36 25

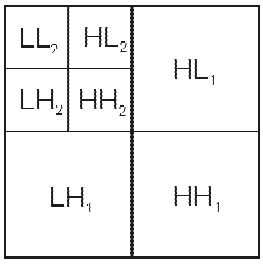
1 0 1 1 1 0 1 0 1 …….. 1 0 0

5 16 5 5 37 0 2 0 17 …….. 2 36 25

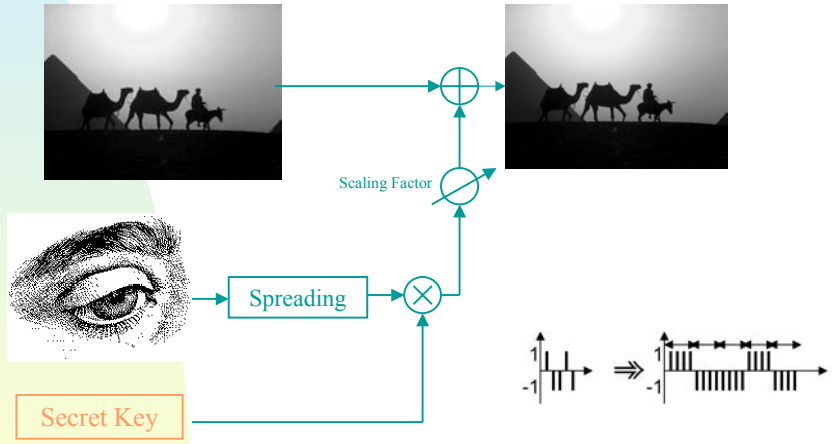
Watermarked Coefficients

Wavelet Watermarking Techniques

The DWT Transform separates the image into a lower resolution approximation (LL) as well as horizontal (HL), vertical (VL) and diagonal (HH) detail components. It is believed to more accurately model aspects of the HVS (Human Visual System)



Spread Spectrum Techniques



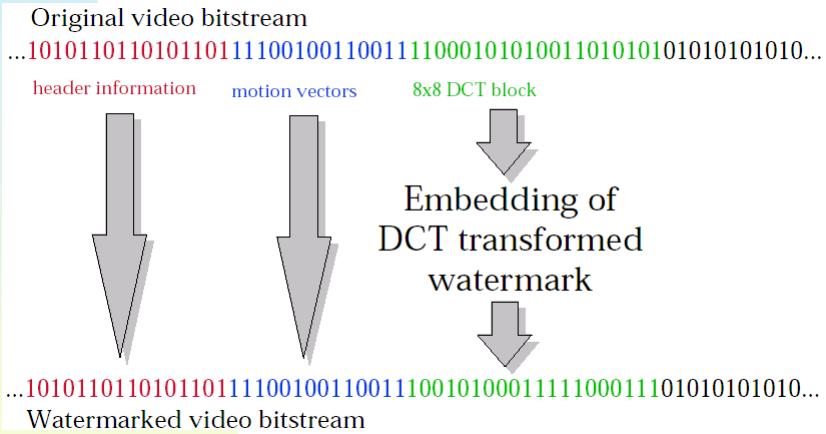
Video Watermarking

- **Uses**
  - **copyright protection**
    - content ownership
    - content misuse
    - proof of purchase
    - conditional access
  - **hidden annotations**
    - labeling
    - indexing and tracking
    - usage and level control
- **Challenges**
  - **must be possible to incorporate into the encoded video**
  - **must work interoperable for compressed and uncompressed video**
  - **may not increase bit-rate**
  - **should not use original**
  - **fast**
  - **new issues in robustness**

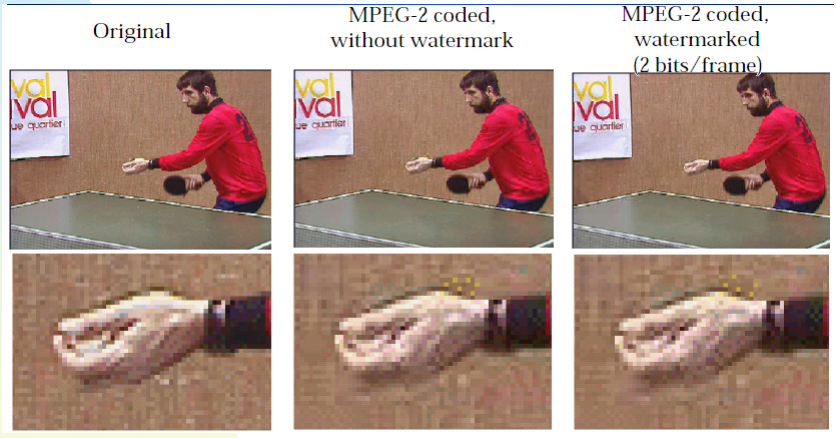
Video Watermarking Techniques

- **Raw Video**
  - assumption: whole non-coded sequence is a collection of single frames
  - watermark embedded in the first frame of GOP
  - pseudo-random signal below the threshold of perception
  - only I-frames encoded
- **Compressed Video**
  - direct manipulation is not possible
  - partly decoded to have access to DCT coefficients

Watermarking of Compressed Video



Watermarking of Compressed Video



Video Watermarking Example

Original

Watermarked

Audio Watermarking

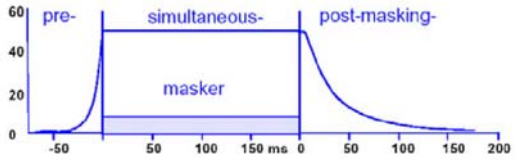
- **Uses**
  - **track audio creation, manipulation and history**
  - **provide different access levels**
  - **tailor an audio signal to users' needs**
- **Characteristics**
  - **new issues in robustness**
  - **techniques exploit the characteristics of human audio system**
    - imperfect detector
    - *masking* phenomenon - a component is imperceptible in the presence of another signal (marker)

Audio Watermarking Types

- **Frequency Masking**
  - **masking between frequency components in the audio signal.**
  - **if two signals which occur simultaneously are close together in frequency, the stronger masking signal may make the weaker signal inaudible.**
  - **readily obtained from the current generation of high quality audio codecs**

Audio Watermarking Types

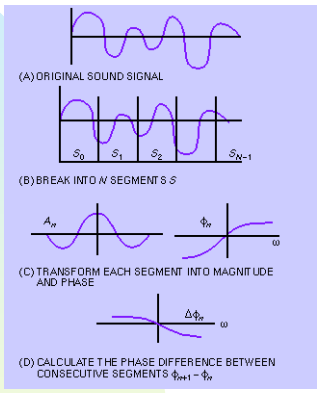
- Temporal Masking
  - ◆*pre-masking* - weaker signals inaudible after the stronger masker is turned off (5-20 ms before the stronger masker is turned on)
  - ◆*post-masking* - 50-200 ms after the masker is turned off.

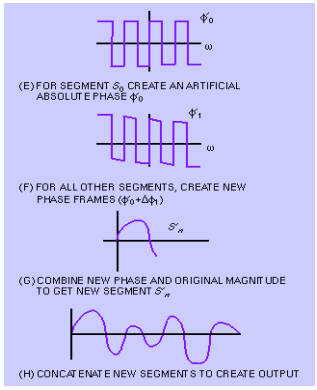


Audio Watermarking Techniques

- Low-Bit Coding
- Phase Coding
- Direct Sequence Spread Spectrum (DSSS)
- Frequency Hopped Spread Spectrum (FHSS)
- Echo Coding

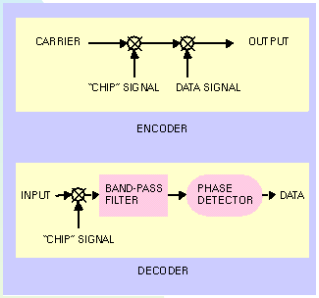
Phase Coding

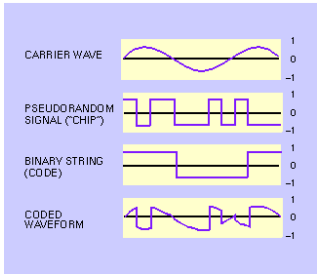




The phase coding method substitutes the phase of an initial audio segment with a reference phase that represents the data. The phase of subsequent segments is adjusted in order to preserve the relative phase between segments.

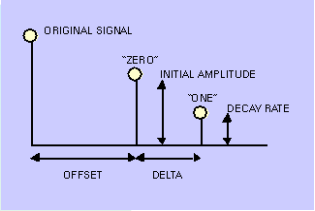
Spread Spectrum Techniques

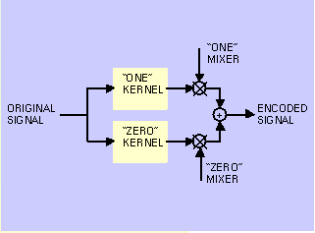




The basic spread spectrum technique is designed to encode a stream of information by spreading the encoded data across as much of the frequency spectrum as possible. This allows the signal reception, even if there is interference on some frequencies.

Echo Coding

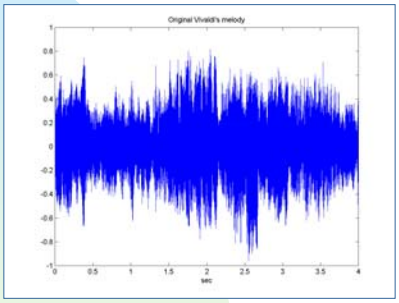




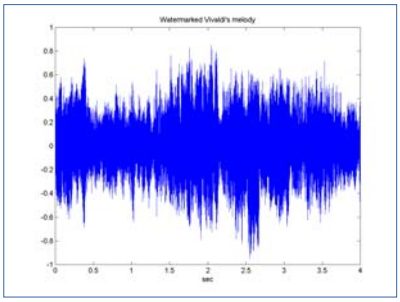
- **Echo data hiding embeds data into a host audio signal by introducing an echo. The data are hidden by varying three parameters of the echo: initial amplitude, decay rate, and offset**

- **The coder uses two delay times, one to represent a binary one (offset) and another to represent a binary zero (offset + delta).**

Audio Watermarking Example



Original



Watermarked

	Original	Watermarked
Echo Coding		
Phase Coding		
DSSS		
Frequency Hopped Spread Spectrum		
Frequency Masking		

3D Watermarking

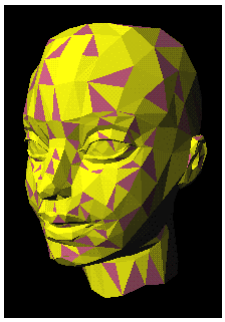
- **Uses**
  - **more CAD-based 3D data entering www - VRML scenes => copyright-related problems**
- **Challenges**
  - **low volume of data**
  - **handling and editing involves complex geometrical and topological operations**
  - **no unique representation of data**
  - **no implicit order of data**
  - **synchronization problems**
  - **new issues in robustness**

3D Watermarking Techniques

- **Shape**
  - **mesh-altering methods**
    - Tetrahedral Volume Ratio algorithm
    - Triangle Similarity Quadruple algorithm
  - **topology altering methods**
    - Mesh Density Pattern algorithm
- **Shape attributes -** vertex colour, vertex texture coordinates, line colour, face colour, volume colour, etc.
- **Animation parameters -** camera position and orientation, face and body animation parameters, parametrized position of eyes, tongue, angle of joints, etc.

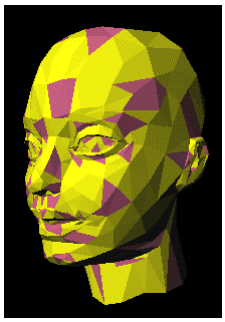
Tetrahedral Volume Ratio Algorithm

- **Technique:**
  - A ratio of volumes of a pair of tetrahedrons is the embedding primitive
  - accept triangular meshes as input
- **Advantages:**
  - does not require cover-3D-model for extraction
  - survives affine transformation
- **Drawbacks:**
  - destroyed by topological modifications (re-meshing, randomization of vertex coordinates) and geometrical transformations



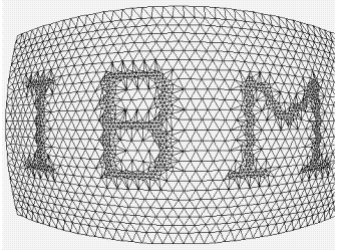
Triangle Similarity Quadruple Algorithm

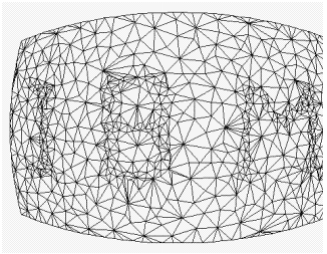
- **Technique:**
  - embedded primitive - a pair of dimensionless quantities that defines a set of similar triangles
- **Advantages:**
  - does not require the original cover-3D-model
  - withstand translation, rotation, and uniform-scaling transformations.
- **Drawbacks:**
  - destroyed by a randomization of coordinates, by a more general class of geometrical transformation, or by an extensive topological alteration such as re-meshing.



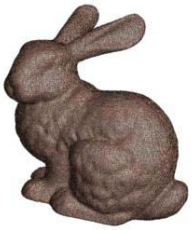
Mesh Density Pattern Embedding

- **Technique:**
  - generates polygonal mesh models given curved surface models as inputs
  - embeds a visible pattern by modulating the sizes of triangles in the output mesh
- **Advantages:**
  - withstands practically every geometrical transformations
- **Disadvantages:**
  - not immune to polygonal simplification and other topology manipulations





3D Watermarking Example

Head	Bunny	Dragon	
			Original
			Watermarked


Questions?