ON VISIBLE WATERMARKING SCHEMES

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OUTLINE

• Introduction
• Attacking visible watermarking schemes
  – Is visible watermarking robust?
• Unseen Visible Watermarking
  – Between visible and invisible watermarking...
• Conclusions
DATA HIDING TECHNOLOGIES

Data hiding

- Steganography
  - Imperceptible data embedding
    - Non-robust data embedding
  - Visible data embedding
    - Robust data embedding

- Watermarking
  - Imperceptible watermarking
  - Fragile watermarking
  - Robust watermarking
  - Visible watermarking
• Watermarking is traditionally an important mechanism applied to physical objects, such as bills, papers, garment labels, product packing.

• The watermark is hidden from view during normal use, and only become visible by adopting a special viewing process.

• The watermark carries information about the object in which it is hidden.
- Embedding into digital contents
- Explicit extraction module
- Watermark information often related to the content
- Conflicting criterions
  - High fidelity
  - Strong robustness
  - Large capacity
Unobtrusive but visible patterns are often embedded into Web pictures or printed documents to guard ownership or indicate author information.

- **Extraction**
  - Recognized by human eyes directly, without involving explicit extractors.

- **Protection**
  - Providing active protection.

- **Robustness**
  - Mark removal involves costly user interventions and professional skills in fine arts.

- **A field receiving relatively less attention**
  - As compared with invisible watermark.
ATTACKING VISBILE WATERMARKING SCHEMES
STATE-OF-THE-ART

  - US Patent 7130442, Protecting images with an image watermark
  - Perceptually uniform color spaces are used
    - CIE 1976 (L*a*b*)
  - Embedding
    \[
    \hat{L}_{m,n} = L_{m,n} + \frac{\mu_{m,n} - \mu_r}{\mu_A - \mu_r} \cdot \frac{L_w}{38.667} \cdot \left( \frac{L_{m,n}}{L_w} \right)^\frac{2}{3} \Delta L
    \]
- Important extensions
  - Video watermarking
  - Local features and DCT statistics are adopted
  - Dual watermarking
A GENERAL MODEL

• Embedding
  – $I' = k_1 * I + k_2 * W$
    • $k_1, k_2$: weighting factor

• Perceptibility of host image details
  – $D(E_I(I), E_I(I')) < T_I$
    • $D$: distance measure,
    • $E_I()$: feature extraction operation, *edge* information shall be included

• Visibility of embedded watermark patterns
  – $D(E_W(W), E_W(I')) < T_W$
    • $E_W()$: feature extraction operation, *shape* information shall be incorporated
Goal

- Restoring the marked area in host images
- Completely removing or seriously distorting watermark patterns

Constraints

- Manually selecting the contour of watermark patterns is inevitable
- Only information within marked image can be used
  - Pixel information surrounding the marked pattern
  - Remaining information within the marked pattern

Existing solutions

- Image recovery
  - Interpolation
  - Inpainting
Interpolating marked areas based on surrounding pixel information
- Suitable for recovering thin or tiny watermark patterns
- Simple and fast
- Obvious blurs occur at edge regions within host images
**Image inpainting**

- The process of reconstructing lost or deteriorated parts of images and videos
  - Iterative approaches considering the isophote directions around the pixels to be recovered
- Good for areas covered by **thin** mark patterns but failed for **thick** patterns occupied areas
  - Information **far from the border** cannot be successfully predicted
• Image recovery schemes recover deteriorated areas with information provided by surrounding pixels only
• However, visible watermarking is in fact a problem easier than image recovery
  – Edge information within marked area can be further utilized to correctly recover areas occupied by thin lines or large mark patterns

A deteriorated image

A visibly marked image
THE PROPOSED SCHEME

Start
(Given a visibly marked image)

Edge detection

Recover nearby flat areas

Inpainting

End

An illustrative example

A real example
EXPERIMENTAL RESULTS

F-16
PSNR=34.50

Lena
PSNR=33.33

Fruits
PSNR=36.28
- The proposed scheme failed in highly textured areas
  - The correlations between pixels in textured areas are too low to be useful clues for recovery

Fruits
PSNR=29.20
TO ENHANCE ROBUSTNESS

- Embedding into more secure areas
  - Hiding visible watermarks into highly-textured or gradient-colored areas

- Use more secure watermark patterns
  - Adequate increasing the border complexity of watermark patterns

- Hiding dual watermarks
  - Invisible fragile watermarking can help to guard the potential to remove visible watermark
UNSEEN VISIBLE WATERMARKING
Visible vs. Invisible (1/2)

- Visible Watermarking
  - Pros
    - Viewing auxiliary information clearly and directly
    - Easy implementation
  - Cons
    - Visual quality degradation
    - Suitable for human-readable messages only
Invisible watermarking

- **Pros**
  - Good visual quality
  - Machine readability *(message type)*

- **Cons**
  - Robustness and security are still under question
  - Explicit extraction modules are required
UNSEEN VISIBLE WATERMARKING !?
• Value-added auxiliary information delivery
  • Users of receivers lacking update capability, such as out-of-date TVs, can still enjoy the convenience provided by metadata
  • Fidelity of cover works does not degrade
  • No additional deployment cost is required
**IMAGE ENHANCEMENT AND REAL-WORLD WATERMARK**

- **Raw image**
- **Image Enhancement e.g. Histogram Equalization**
- **Processed image with revealed details**

Bills with imprinted watermark patterns

Seeing against the light source

Visualized watermark patterns

Central Bank

100
Many display devices possess power-law input-output characteristics:

- \( q = cp^r \),
  - \( q \): input intensity
  - \( p \): output intensity
  - \( r: 1.8 \sim 2.5 \)

- Gamma correction
  - \( r < 1 \) to produce corrected output
UVW BASED ON GAMMA CORRECTION

watermark

original image (whole black)
remain the same
change intensity value to 3

stego image

Apply Gamma Correction
intensity 0 → 0
intensity 3 → 105
disclosed image
UVW EMBEDDING

**Embedding**

- **Original Image**
- **Mapping Function**
- **Watermark**
- **Stego Image**

**Processes:**
- **Denoising**
- **Embedding Region Selection**
- **Watermark Strength Calculation & Bit Embedding**

**Questions:**
- Is the region good enough?
- Yes or No
DISCLOSING UVW

input

Stego Image

output

Mapping Function

input

Applying Mapping Function

output

Disclosing

Unseen Visible Watermark

Originally Unseen Finally Visible Watermark

zoom in
(a) Applying UVW on Y channel in YCbCr color space;
(b) Disclosing image by image processing software;
(c) (d) Snapshots of (a) and (b) on a Lenovo X60 laptop monitor.
UVW FOR UNCOMPRESSED VIDEO

- UVW for Different video frames
- Average PSNR: 50.14
UVW FOR H.264
COMPRESSED VIDEO

QP=6  QP=12  QP=18  QP=24
Documents printed using HP LaserJet 4350. (a) Normal printing settings (b) using the optimal printing option.
AN INTERESTING BUT USEFUL SIDE-EFFECT

Changing the Relative Viewing Angle to LCD Monitors
Changing of Contrast Condition

Exposure: 1/1.7sec ; Shutter: 1/2sec ; Aperture: F/8 ; Focal Length: 7.40mm.
More about UVW
UVW BASED ON HISTOGRAM EQUALIZATION

(a) Unseen Visible Watermarking

(b) best intensity

(c) (d)
1. These two schemes could have more than one best intensities.
2. They increase content versatility.
More built-in operations of graphic cards and monitors:
- Gamma correction
- Brightness adjustment
- ……
In some application scenarios, machine-readable messages are required.

1. Two-dimensional barcodes, such as QR Code, are widely used.
   - Large information capacity and error correction abilities
   - Public extractor

2. Difficult to integrate 2D barcodes with existing visible watermarking schemes
   - Obvious image contents seriously interfere unobtrusive barcode patterns.
QUANTITATIVE PERFORMANCES

- Capacity
- Robustness
A simple example of visual cryptography

- Visual cryptography was pioneered by Moni Naor and Adi Shamir in 1994
  - Can be generalized as n-party visual secret sharing schemes
- Visual cryptography is illustrative but lacks feasible application value since it is quite unnatural to deliver noise-like shares
DECIPHERING WITH TV AND PROJECTOR
EXPERIMENTAL RESULTS: THE TWO-PROJECTOR CASE

Experimental settings

Single-share projection

Disclosed secret messages
EXPERIMENTAL RESULTS: THE TV + PROJECTOR CASE
STATISTICAL STEGANALYSIS

RS Steganalysis for UVW

Watermark Size

RS Detection Ratio

- UVW, Δ=1
- UW+VC, Δ=1
- UVW, Δ=3
- UVW+VC, Δ=3
- Original
EMBEDDING COMPLEXITY

Embedded pattern length: 16384 bits
Image size: 512x512

Graph showing time (Sec.) for UVW, SSWM, and HWWM methods.
COMPARISONS (1/3)

Invisible Watermarking

Fidelity under normal viewing condition

Robustness against malicious removal

Robustness against geometric distortions

Inverse of embedding complexity

Inverse of deployment cost

Allowable message types

Content versatility

Capacity
Visible Watermarking

- Fidelity under normal viewing condition
- Robustness against malicious removal
- Robustness against geometric distortions
- Capacity
- Content versatility
- Allowable message types
- Inverse of embedding complexity
- Inverse of deployment cost
- Allowable message types
Unseen Visible Watermarking

- Fidelity under normal viewing condition
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- Inverse of deployment cost
RELATIVE PUBLICATION

Visible watermarking technologies can provide active and effective protection for digital images and video.

The robustness of visible watermarking can be further enhanced.

Unseen visible watermarking can provide both advantages of visible and invisible watermarking schemes and is suitable for certain application scenarios.

Integrating visible and invisible watermarking schemes can provide better protection for digital contents.