Digital Watermarking and Steganography

by Ingemar Cox, Matthew Miller, Jeffrey Bloom, Jessica Fridrich, Ton Kalker

Chapter 5. Watermarking with Side Information

Lecturer: Jin HUANG

2015

Blind Embedding

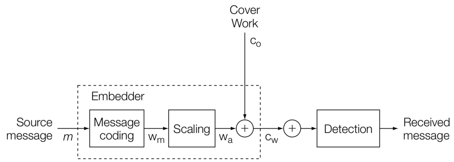


FIGURE 5.1
Watermarking with blind embedders.

Informed Embedding

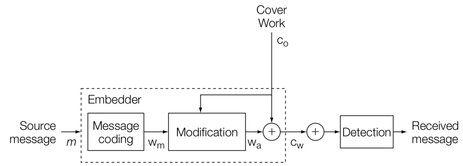


FIGURE 5.2
Watermarking with informed embedding.

- The simplest case: E_FIXED_LC.
- Embedding as an optimization problem.
  - Fidelity
  - Robustness

Informed in Block Strategy

How to use the cover work?

Informed in Block Strategy

How to use the cover work?

- Distribute Δ to blocks with different strength.
- Locally amplified or attenuated the added watermark pattern to improve fidelity.
- Relative error for fidelity.

5.1 Informed Embedding

Fidelity Constraints

In the framework of $\mathbf{c_w} = \mathbf{c_o} + \mathbf{w_a}$

- $\mathbf{c_w} = \mathbf{w_m} \Longrightarrow \mathbf{w_m} = \mathbf{w_{a-}c_o}$.

Looks stupid?

- Directly in media space: does not resemble the original Work at all.
- But in marking space: occasionally feasible.

$$\mathcal{T}(\mathbf{c_o} + \mathbf{w_a}) = \mathbf{v_w} \approx \mathbf{v_a}$$

- Usually: $\mathbf{v_w}$ is between $\mathbf{v_a}$ and $\mathbf{v_o}$.

The Optimization Problem

- Maintain perceptual distortion (fidelity), but maximize robustness.
- Maintain robustness, but minimize perceptual distortion (for fidelity).
  - E_FIXED_LC
- Or even both
  - If no possible, relax the constraints.

Measurement of Robustness

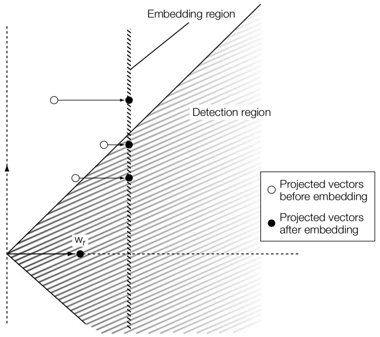
Via detection value:

- $z_{lc} = \tau_{lc} + \beta$: E_FIXED_LC

Unfortunately, it does not work for other detection statistics.

- z_{nc}: larger z_{nc} does not mean better robustness.

E_FIXED_LC under z_{nc}



E_FIXED_CC for z_{cc}

Has zero mean: NC $\Rightarrow$ CC.

Fix the normalized correlation at some desired value: τ_{nc}.

- Find the closest point on the cone related to τ_{nc}.
- The point is on the plane $\mathbf{w_r} - \mathbf{v_o}$.

$$\mathbf{X} = \frac{\mathbf{w_r}}{\|\mathbf{w_r}\|}$$
$$\mathbf{Y} = \frac{\mathbf{v_o} - \mathbf{X}(\mathbf{v_o} \cdot \mathbf{X})}{\|\mathbf{v_o} - \mathbf{X}(\mathbf{v_o} \cdot \mathbf{X})\|}.$$

Some Simple Geometry

Position of $\mathbf{v_o}$

$$x_{\mathbf{v_o}} = \mathbf{v_o} \cdot X, \quad y_{\mathbf{v_o}} = \mathbf{v_o} \cdot Y.$$

Upper border of the detection region (desired embedding region)

$$x(t) = t\cos(\tau_{nc}), \quad y(t) = t\sin(\tau_{nc}), \quad t > 0.$$

An Optimization

The distance from $\mathbf{v_o}$ to a point on the border:

$$\begin{aligned} d^2(t) &= (x(t) - x_{\mathbf{v_o}})^2 + (y(t) - y_{\mathbf{v_o}}) \\ &= (t\cos(\tau_{nc}) - x_{\mathbf{v_o}})^2 + (t\sin(\tau_{nc}) - y_{\mathbf{v_o}}) \\ &= t^2 - 2\left(\cos(\tau_{nc})x_{\mathbf{v_o}} + \sin(\tau_{nc})y_{\mathbf{v_o}}\right)t \\ &\quad + (x^2_{\mathbf{v_o}} + y^2_{\mathbf{v_o}}). \end{aligned}$$

So, the closest point $\mathbf{v_w}$ is $(x(t), y(t))$ with t

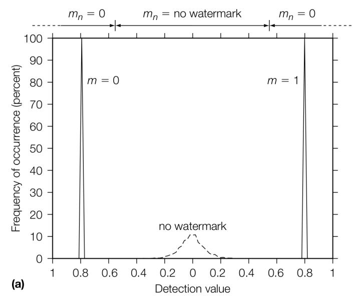
$$\min_t d(t) \Longrightarrow t = \cos(\tau_{nc})x_{\mathbf{v_o}} + \sin(\tau_{nc})y_{\mathbf{v_o}}.$$

Experiments

In E_BLK_FIXED_CC/D_BLK_CC

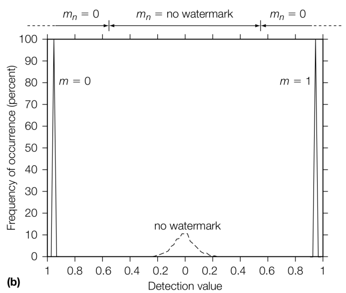
- Adding white Gaussian noise, with a standard deviation of 10.

Performance



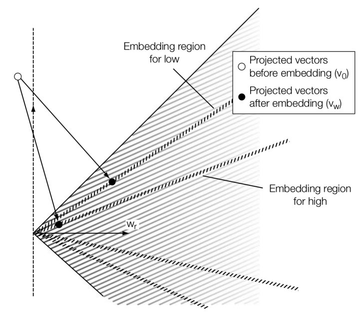
$\tau_{nc} = 0.55, \beta = 0.25, 85\%$ *correct.*

Performance



$\tau_{nc} = 0.55, \beta = 0.4, 66\%$ *correct.*

Performance



Robustness Measurement

Amount of white Gaussian noise that can be added to the embedded vector, $\mathbf{v_w}$, before it is expected to fall outside the detection region.

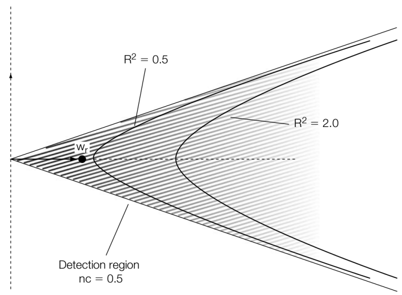
Add Noise

$$z_{nc}(\mathbf{v_w} + \mathbf{n}) = \frac{(\mathbf{v_w} + \mathbf{n}) \cdot \mathbf{w_r}}{\|\mathbf{v_w} + \mathbf{n}\| \|\mathbf{w_r}\|}$$
$$\approx \frac{\mathbf{v_w} \cdot \mathbf{w_r}}{\sqrt{\mathbf{v_w} \cdot \mathbf{v_w} + \mathbf{n} \cdot \mathbf{n}} \|\mathbf{w_r}\|}$$

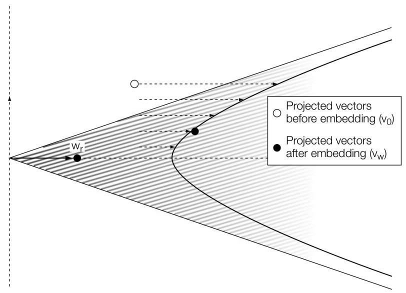
The noise causes $z_{nc} < \tau_{nc}$:

$$\|\mathbf{n}\|^2 \leq \left(\frac{\mathbf{v_w} \cdot \mathbf{w_r}}{\tau_{nc} \|\mathbf{w_r}\|} \right)^2 - \|\mathbf{v_w}\|^2$$

Illustration

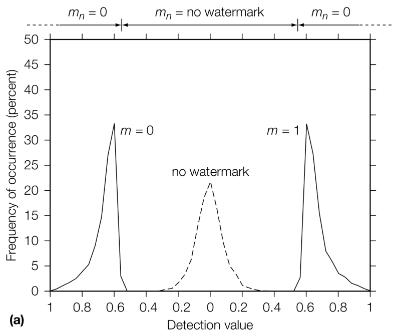


Illustration



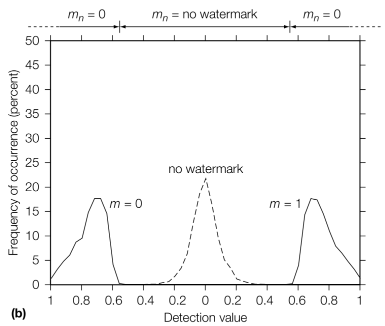
For given robustness R, the embedder must find the point $\mathbf{v_w}$, on the hyperboloid that is closest to a given point $\mathbf{v_o}$.

Performance



$R^2 = 10.$

Performance



$R^2 = 30.$

Presentation: 8.1

Evaluating Perceptual Impact of Watermarks.

In addition:

- In color image: CIE
- `http://en.wikipedia.org/wiki/Color_difference`