Digital Watermarking and Steganography

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Chapter 5. Watermarking with Side Information

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Blind Embedding

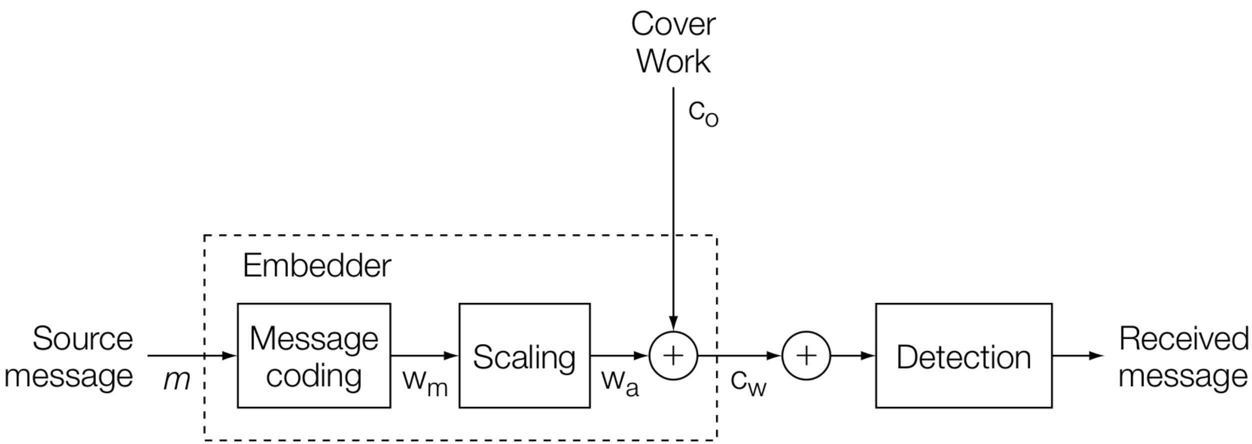


FIGURE 5.1

Watermarking with blind embedders.

Informed Embedding

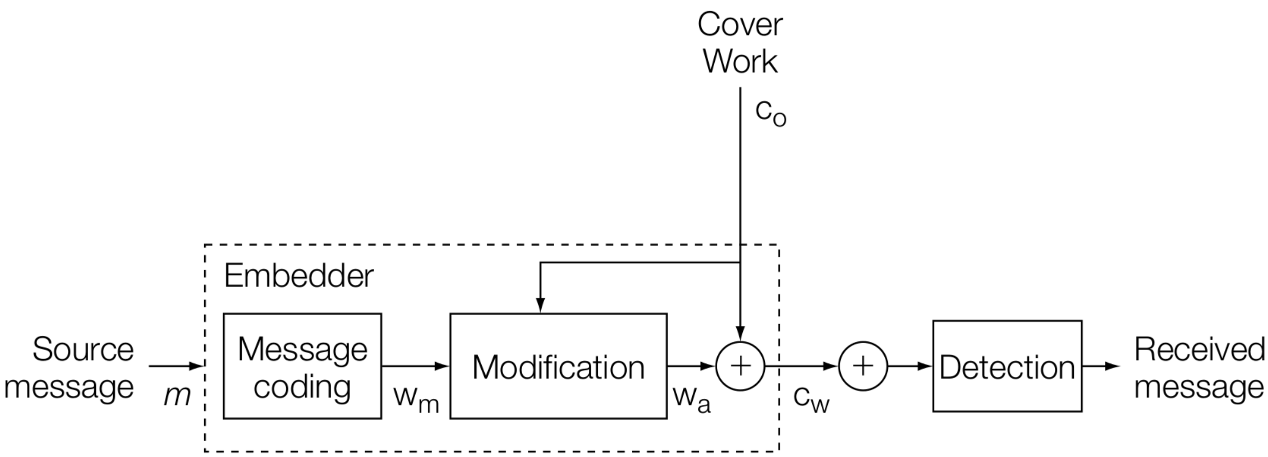


FIGURE 5.2

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?

平衡 fidelity 和 robustness

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 $\mathbf{c_w} = \mathbf{c_o} + \mathbf{w_a}$

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

Looks stupid?

直接、去掉 cover work.

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

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

  - E.g. 1% of the pixels.

- 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:

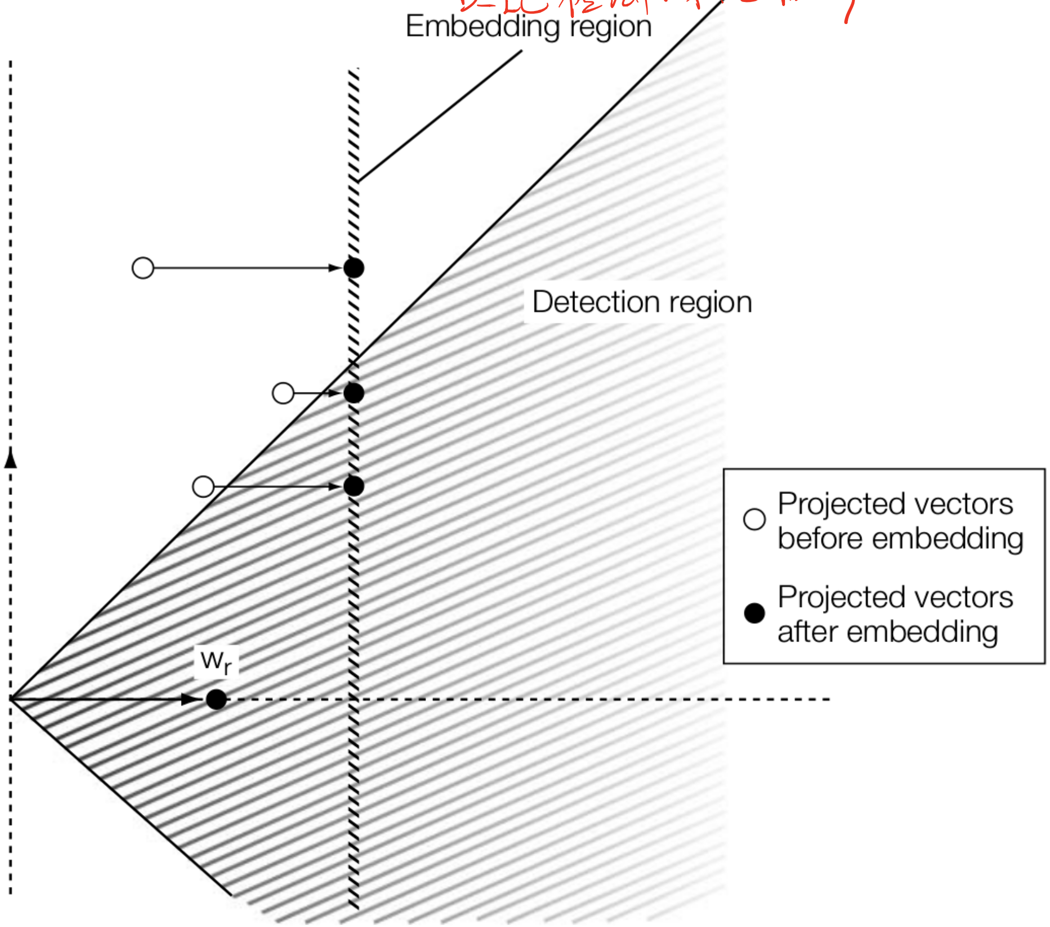
- $z_{lc} = \tau_{lc} + \beta$: E_FIXED_LC

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}

D_LC检测域不是锥形

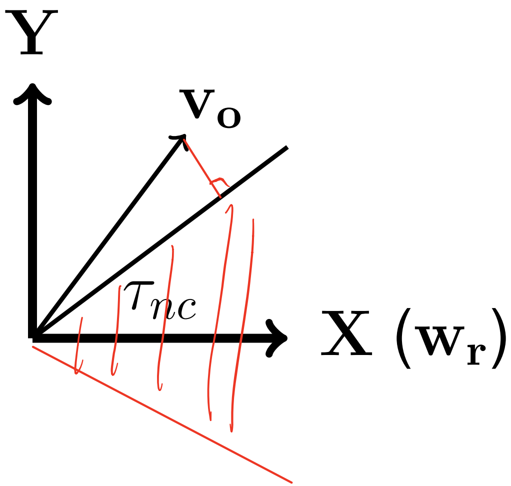


E_FIXED_CC for z_{cc}

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)

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

robustness

An Optimization

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

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

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

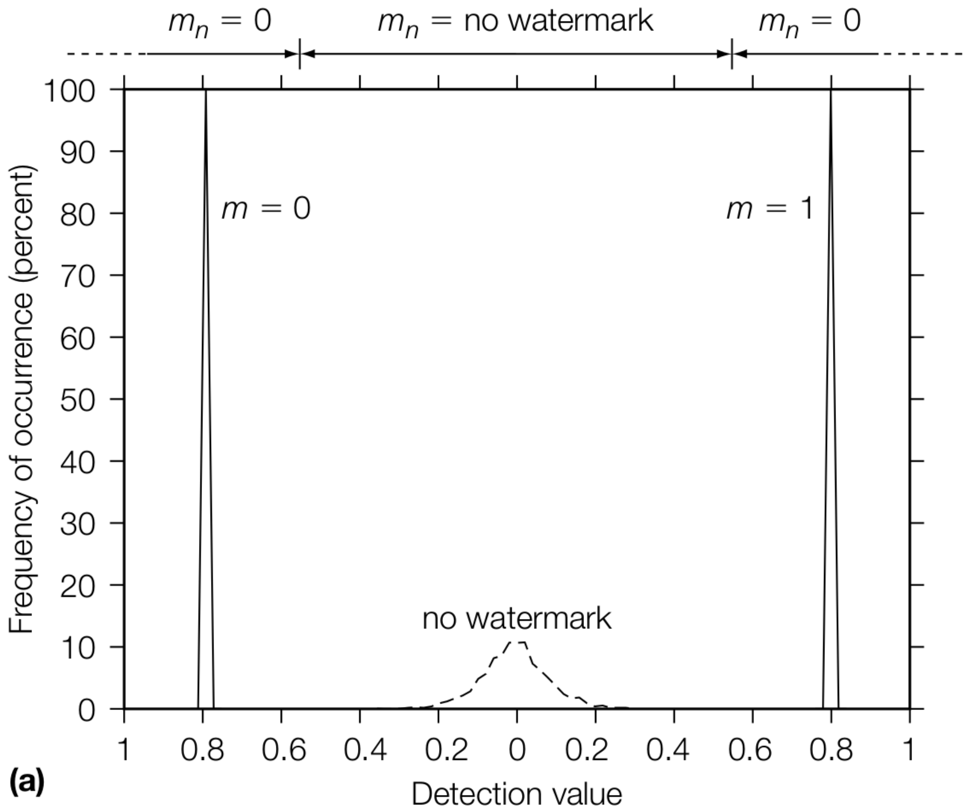
fidelity $\Rightarrow$ $$\min_t d(t) \implies t = \cos(\theta_{nc})x_{\mathbf{v_o}} + \sin(\theta_{nc})y_{\mathbf{v_o}}.$$

Experiments

In E_BLK_FIXED_CC/D_BLK_CC

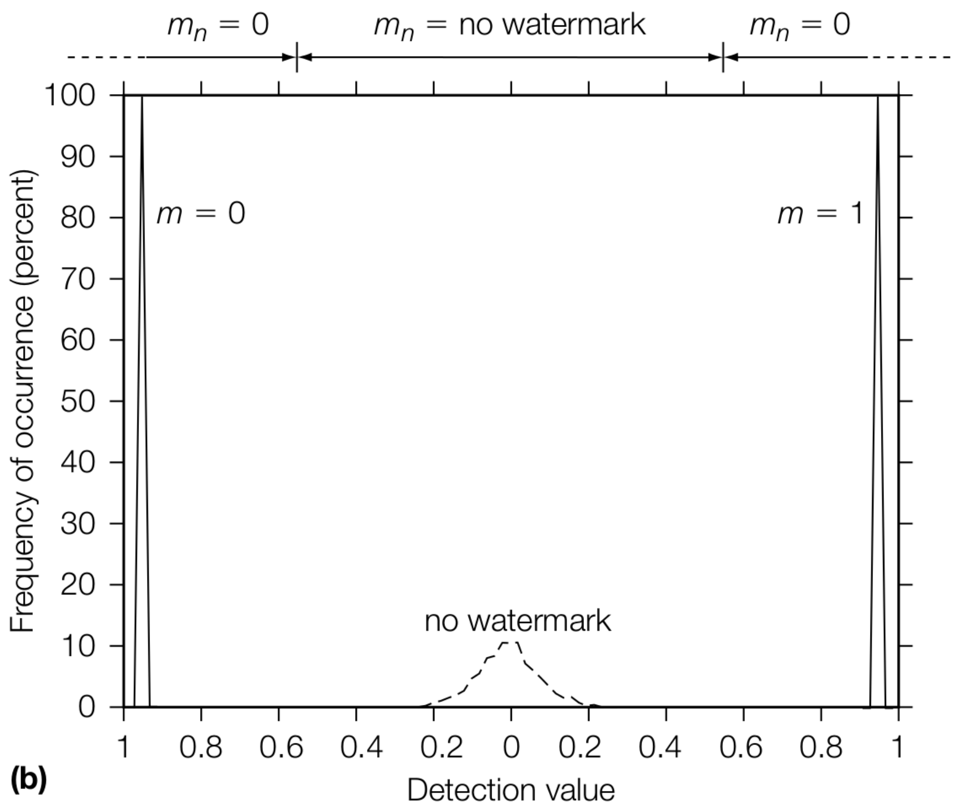
- Adding white Gaussian noise, with a standard deviation of 10.

Performance



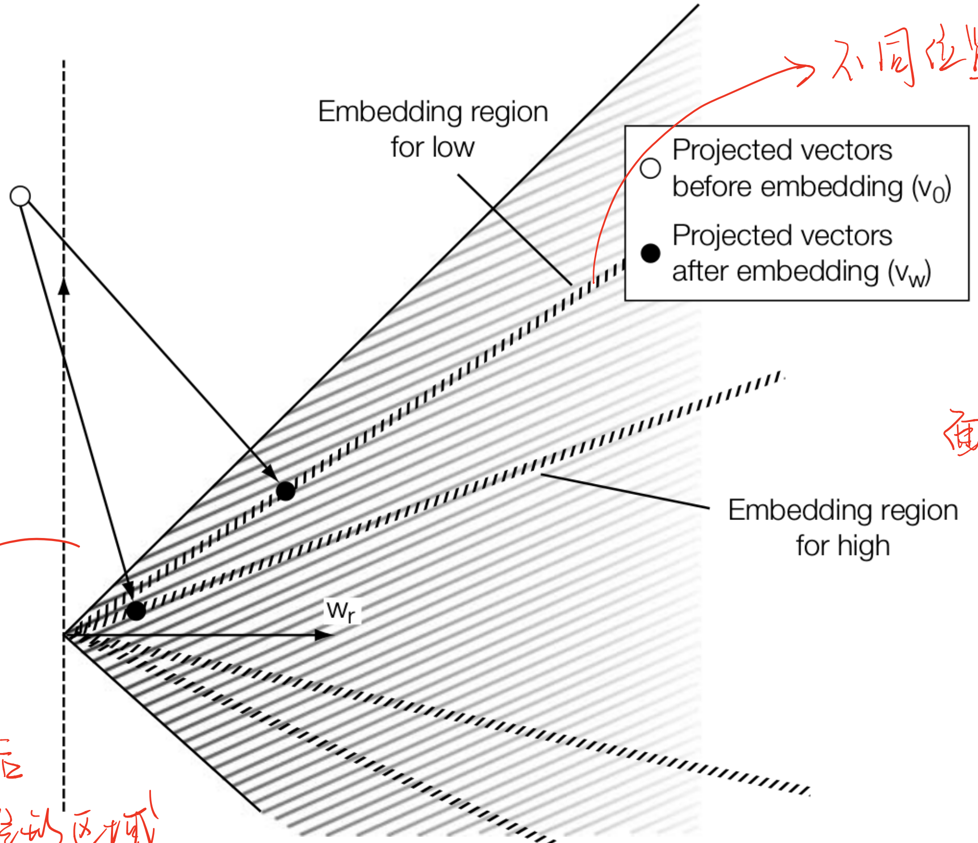
$\tau_{nc} = 0.55, \beta = 0.25$, 85% *correct.*

Performance



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

Performance



不同位置抵抗扰动能力不同

面积变小一

β 个
离边界距离越近
细微扰动后
就会跳出相应区域

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

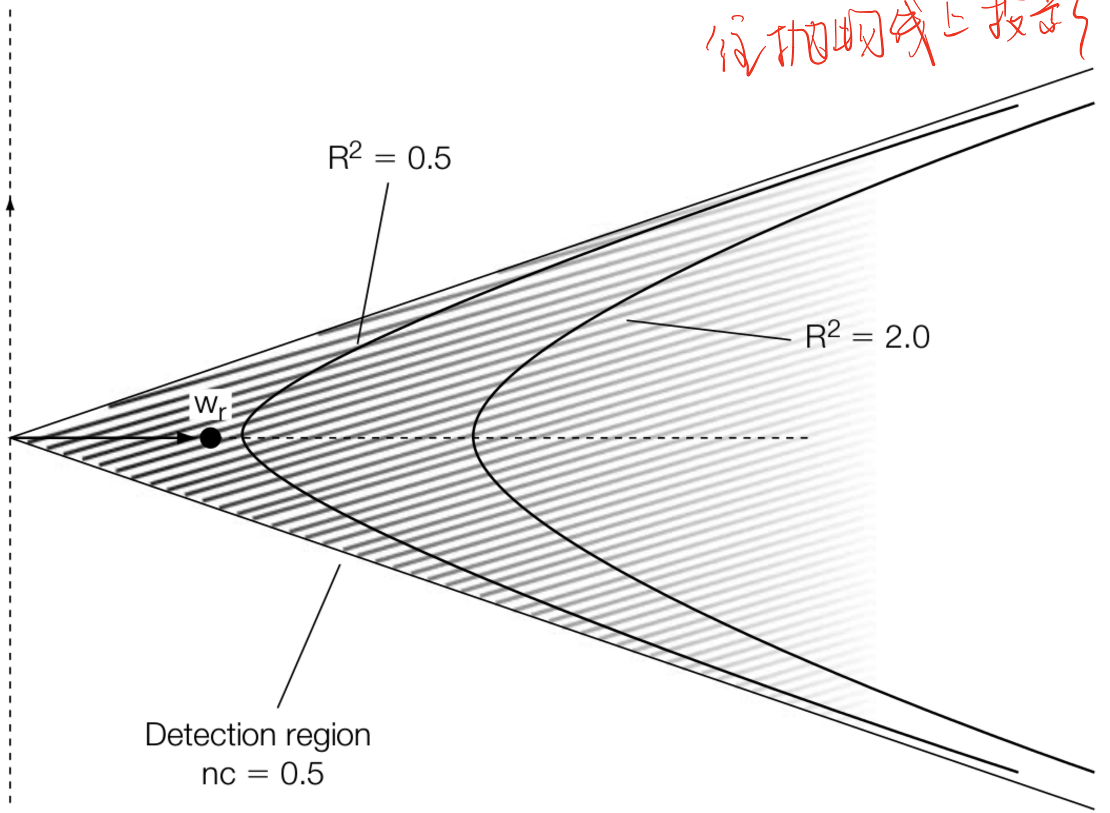
$$
\begin{aligned}
z_{nc}(\mathbf{v_w} + \mathbf{n}) &= \frac{(\mathbf{v_w} + \mathbf{n}) \cdot \mathbf{w_r}}{\|\mathbf{v_w} + \mathbf{n}\| \|\mathbf{w_r}\|} \\
&\approx \frac{\mathbf{v_w} \cdot \mathbf{w_r}}{\sqrt{\mathbf{v_w} \cdot \mathbf{v_w} + \mathbf{n} \cdot \mathbf{n}} \|\mathbf{w_r}\|}
\end{aligned}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

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

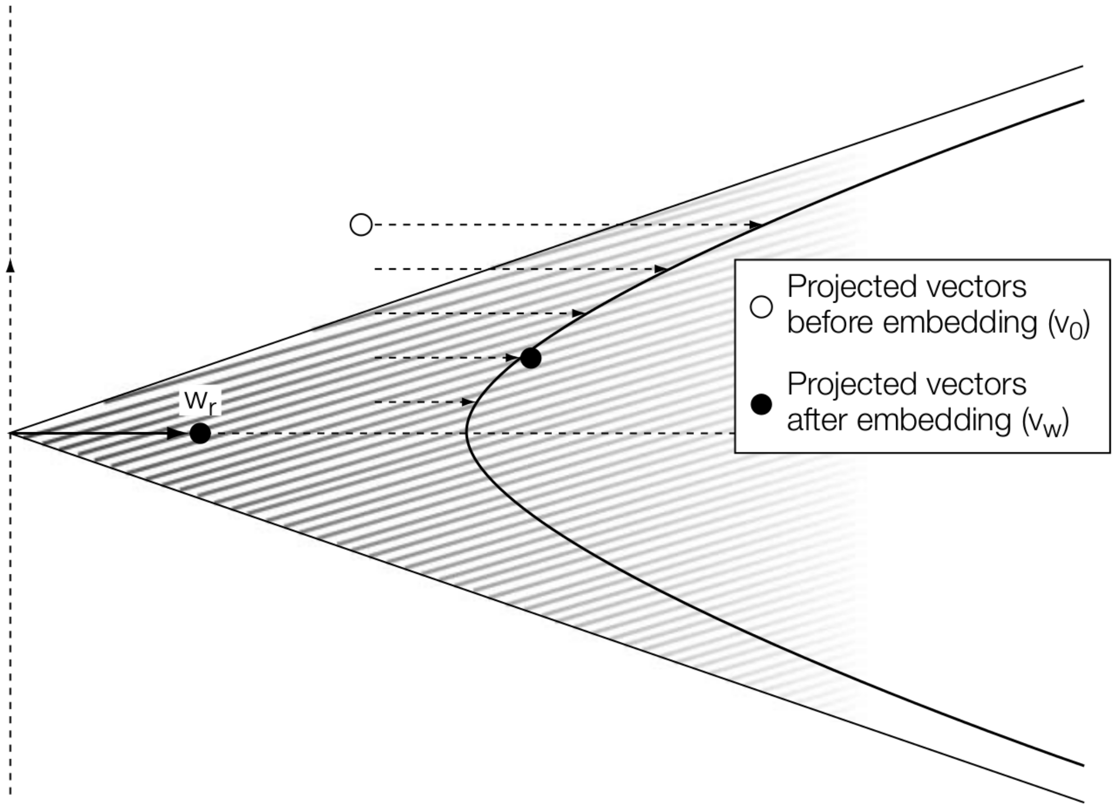
$$
R^2 = \|\mathbf{n}\|^2 \overset{>}{\cancel{\leq}} \left(\frac{\mathbf{v_w} \cdot \mathbf{w_r}}{\tau_{nc} \|\mathbf{w_r}\|} \right)^2 - \|\mathbf{v_w}\|^2
$$

Illustration

往抛物线上投影

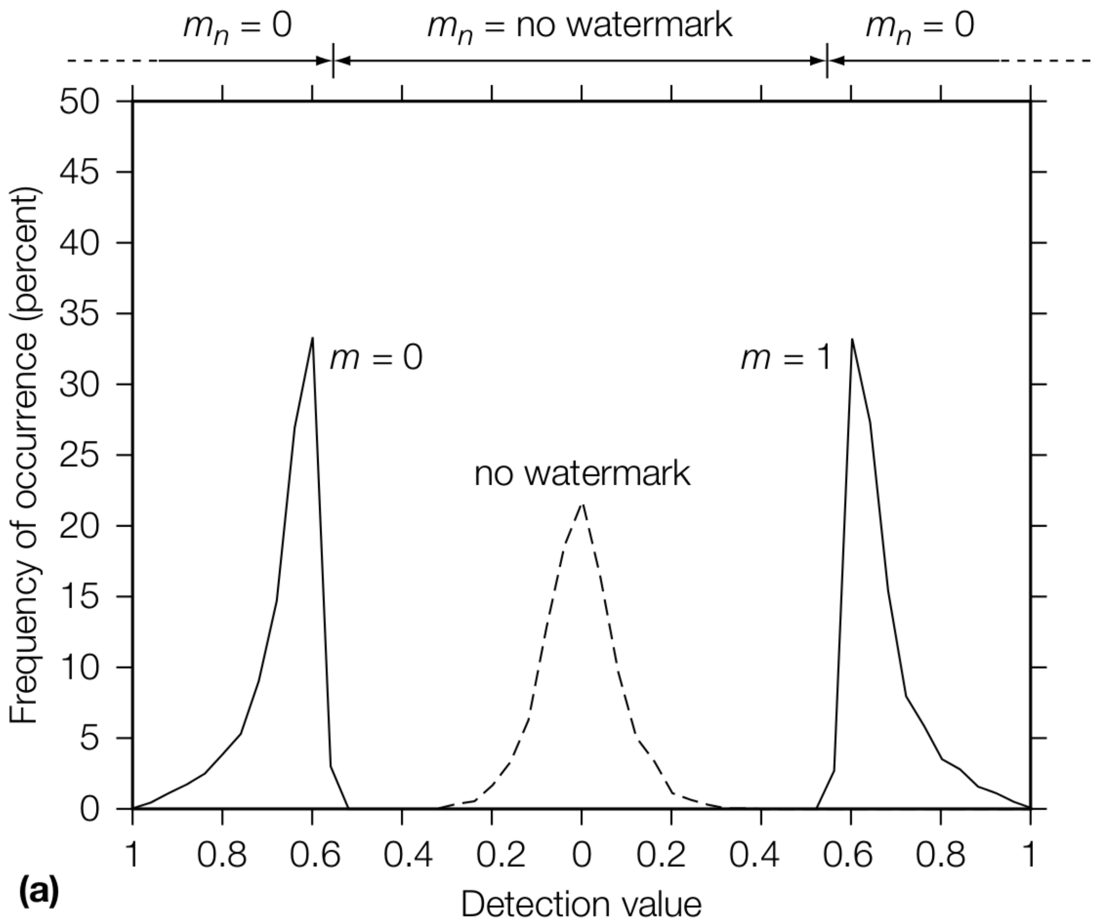


Illustration



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

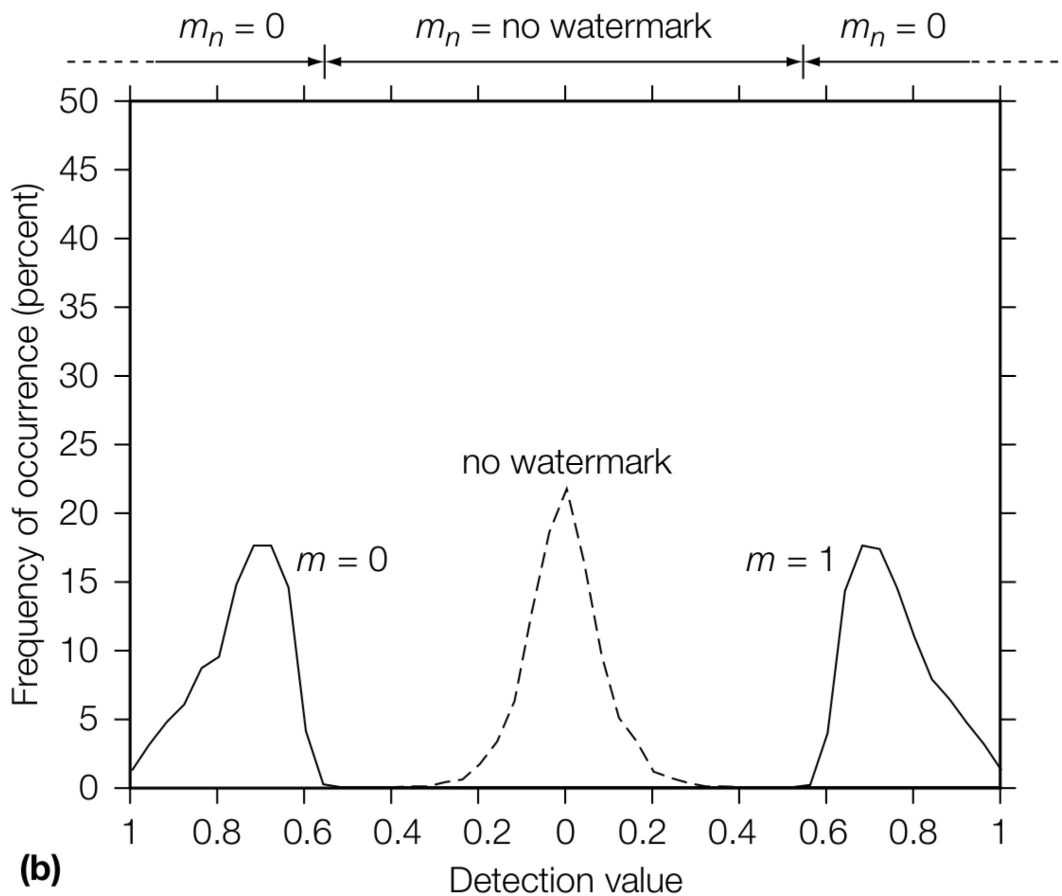
Performance



(a)

$$R^2 = 10.$$

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