SESSION 5: APPLICATIONS & ADVANCED TOPICS

• Data-Hiding Codes for Images
• Desynchronization Attacks
• Authentication
• Steganography
• Fingerprinting
Data-Hiding Codes for Images

- Wavelets $\rightarrow$ approximate parallel-Gaussian model
With embedded data

\[ D_1 = 10 \]

Attacked

\[ D_2 = 50 \]
Decoding Performance for 3 QIM schemes

Operational $P_{be}$ vs $D_2/D_1$ for Lena with $D_1 = 10$.
Rate $R(D_2) = \frac{1}{10} C(D_2)$. 

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Desynchronization Attacks

- Such attacks are perceptually benign but can disable basic detectors
- Delays (fixed or time-varying)
  \[ y(n) = x(n - \theta) + w(n) \]
- Amplitude scaling \textit{(valumetric attacks)}
  \[ y(n) = \theta x(n) + w(n) \]
- Offsets
  \[ y(n) = \theta + x(n) \]
- Erasures and Insertions

Can you read this sentence?
Warping Attack on Lena

lena with ρ=0.995 max shift 15
Desynchronized QIM Decoders

\[ D'_2 = D_2 + \theta^2 \]
\[ D'_2 \sim D_2 + (\theta - 1)^2 \frac{\|x\|^2}{N} \]
\[ D'_2 \sim D_2 + \theta^2 \frac{\|x'\|^2}{N} \]
\Rightarrow \text{catastrophic performance degradation}
Improved QIM Decoders

- Motivation: desync attacks have *benign effect on capacity*
- Use pilot sequences for estimating desync parameters
- Use Reed-Solomon codes for coping with an equal number of insertions & deletions
- Use Davey-Mackay codes for coping with more general insertions, deletions & substitutions
Steganography

- *Existence* of hidden message should be concealed
- Can be addressed in information-theoretic framework
- Additional constraint:
  marked $X$ must be *typical* of host signal distribution
- For instance, capacity is generally *slightly lower* than without steganography constraint:

\[
C(D_1, D_2) = \max_{Q} \min_{A} \left[ I(U; Y | K) - I(U; S | K) \right]_{J(Q, A)}
\]

where $\max_{Q}$ is subject to the constraint $p_{X} = p_{S}$
Authentication

- Probability of error $P_{e,N} = Pr[\hat{M} \neq M]$
- Probability distribution $p(s^N, k^N)$ (iid symbols)
- Composite binary hypothesis test: $H_0$ vs $H_1$; $A$ viewed as a nuisance parameter
- Detection rule: $\hat{M} = \phi(y^N, k^N) \in \{0, 1\}$
Detection Rule

- Probability of false alarm $P_{FA}$ (”false positives”)
  \[ = Pr[\hat{M} = 1|M = 0] \]

- Probability of miss $P_M$ (”false negatives”)
  \[ = Pr[\hat{M} = 0|M = 1] \]

- Probability of error $P_e = Pr[\hat{M} \neq M]$
Optimal Detector

• Given $A$, Likelihood Ratio Test (LRT)

\[
p(y^N, k^N | H_1) \quad \frac{H_1}{H_0} \quad \begin{array}{c} p(y^N, k^N | H_1) > \tau \\ p(y^N, k^N | H_0) < \end{array} \]

is optimal under classical optimality criteria (Bayes, minimax, Neyman-Pearson)

• Two approaches when $A$ is unknown:
  - Assume a prior distribution $p(A)$
    \[ \Rightarrow \phi = \text{simple hypothesis test} \]
  - In some problems, optimal $\phi$ is still a LRT designed under the worst-case $A$
The Authentication Game

• Assume information hider does not know attack channel $A$
• Assume attacker knows WM code $f$ but not secret key $k^N$
• Assume decoder knows WM code $f$ and attack channel $A$
• Constraint on encoder: $f \in \mathcal{F}$
• Constraint on attacker: $A \in \mathcal{A}$
• Solve $\min_{f \in \mathcal{F}} \max_{A \in \mathcal{A}} P_{e,N}(f, A)$
Application to Blind SSM Watermarking

Probability of error as a function of $D_w$ ($D_a = 2D_w$) using Lena and Daubechies’ 9/7 filters
Significance Map

Significance map, D9/7 3–level $D = 6e^{-05}; E = 3e^{-05}$

\[ D_w = 10^{-5} \text{ and } D_a = 2D_w \]
An Optimal Watermark

$D_w = 5 \times 10^{-5}, \; D_a = 2D_w$
Fingerprinting

- $L$ users collude and attempt to remove watermark
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