Modern Steganography

Hiding Information in Plain Sight

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Securing our World through Technology
Modern Steganography

• Applications
  – National Security Applications
  – More than security: $
  – Multimedia and Consumer Applications

• Baby Example

• Fundamental Performance Bounds $\rightarrow$ Practical Implementations
National Security Applications

• Document authentication
  – International communications
• Digital fingerprinting
  – Traitor tracing
• Covert communications
  – February 2001: USA Today reported that Osama Bin Laden used steganography to communicate with operative
Multimedia and Consumer Applications

• Audio
  – Rampant music sharing, violation of copyright laws

• Images
  – Photographers: authenticity and/or copyright
    • 2001: Disney announced plans to digitally watermark every frame of every movie for copyright protection

• Video-on-demand
  – Video sharing

• Broadcast video (*VEIL Interactive*)
  – Broadcast verification
  – Broadcast quality (cropping, time-warping, etc.)
  – Copyright and authentication issues

• Legal, ethical issues
  – Digital Millennium Copyright Act (DMCA)
  – Political power of movie, music industries
“Bootleg copies of Oscar-nominated movies showing up on Internet”
AP Jan. 14, 2004

  - “The Los Angeles Times reported that security features on the tape [Cold Mountain] indicated that it belonged to Ivan Kruglak, an academy member and president of a wireless data communications company.” AP Jan. 15, 2004
  - Fingerprinting based on Philips Research Lab Technology
Oscar Bootlegs 2004

- Fri Jan 16, 2:12 AM ET By Gregg Kilday and Paul Bond (Hollywood Reporter)
- FBI confirmed involvement
- “Illegal copies … have been traced … to character actor Carmine Caridi, a member of the Academy of Motion Picture Arts and Sciences”
- “It was a pretty professional job… all visible markings were removed.”
- “This year the screeners carried invisible markings for the first time; the studios were able to identify the Academy member for whom they had been intended.”
Information Hiding Problems

- Covertext $S_i$: image, video, data
- Key $K_i$: shared information (image, features, where is information hidden)
- Sets of allowable information hiding and attack channels
- Rate $R$: how much information is hidden?
- Probability of Error
- Moulin and O’Sullivan 1997-2003
Baby Version of Problem

Source \rightarrow \text{Encoder} \rightarrow \text{Attack} \rightarrow \text{Decoder} \rightarrow \text{Message}
Information Hiding Constraints

Transparency or unobtrusiveness: $S^n$ and $X^n$ similar using a quantitative measure

Source $S^n$ → Encoder $X^n$ → Attack → Decoder

Message
Attack Channel Constraints

Robustness: $X^n$ and $Y^n$ similar using a quantitative measure
Game Theory View: 
*Information Hider Viewpoint*

- Acknowledge information will be hidden
- Acknowledge existence of adversary
- Publish hiding strategy
  → consistent with standard approaches to cryptography
- Need for secret key for randomized coding
- Need for encoding robustness against broad families of attacks
- Need for decoder to adapt to or be robust with respect to attacks
Game Theory View: 
*Information Attacker Viewpoint*

- Acknowledge that an attack will occur
- Acknowledge intelligent information hiding
- Design attack as if it would be published
- Define goal of attack
- Need for randomized attack, families of attack strategies
- Need to tune attack strategy to different information hiding strategies (robustness of optimal attack)
Information Hiding
Coding Theorems

• Public Game:
  \[ C = \max_{Q \in \mathcal{Q}_1} \min_{A \in \mathcal{A}_1(Q)} I(U; Y) - I(U; S) \]

• Private Game:
  \[ C = \max_{Q \in \mathcal{Q}_1} \min_{A \in \mathcal{A}_1(Q)} I(X; Y | S) \]

• Other:
  \[ C = \max_{Q \in \mathcal{Q}_1} \min_{A \in \mathcal{A}_1(Q)} I(U; Y | K) - I(U; S | K) \]

• Gaussian, squared error game:
  – Public and private games have equal capacity
Practical Implementation

• Distributions on sources
  – Images, video, voice, music
  – Option: base models on successful compression algorithms

• Model real attacks
  – Malicious, benign, unanticipated
  – “Cut-out” of intellectual property; edited photos
Modern Steganography: 
*Hiding Information in Plain Sight*

- National Security Applications
  - Document authentication, fingerprinting, covert communications
- Multimedia and Consumer Applications
  - Audio, images, video, broadcast video
  - Copyright issues, broadcast verification
- Fundamental Performance Bounds
  → Practical Implementations