Multimedia Security: So What's the Big Deal?

Edward J. Delp

Purdue University
School of Electrical and Computer Engineering
Video and Image Processing Laboratory (*VIPER*)
West Lafayette, Indiana

email: ace@ecn.purdue.edu
http://www.ece.purdue.edu/~ace

Multimedia Security

- **“Everything” is digital these days - a copy of a digital media element is identical to the original**
- **How can an owner protect their content?**
- **Are images still “fossilized light”?**
- **What does all of this mean in terms of law?**
  - **What does it mean to own “bits”?**
- **Does any security system really work or does it just make us feel good!**

What Do We Want From a Security System?

- **Access Control**
- **Copy Control**

Þ

Playback Control

Record Control

Generation Control

- **Auditing (fingerprinting)**
  - **– Who did what and when?**

What Do Users Want?

- **Time-shifting**
- **Format-shifting**
- **Single copy (back ups?)**

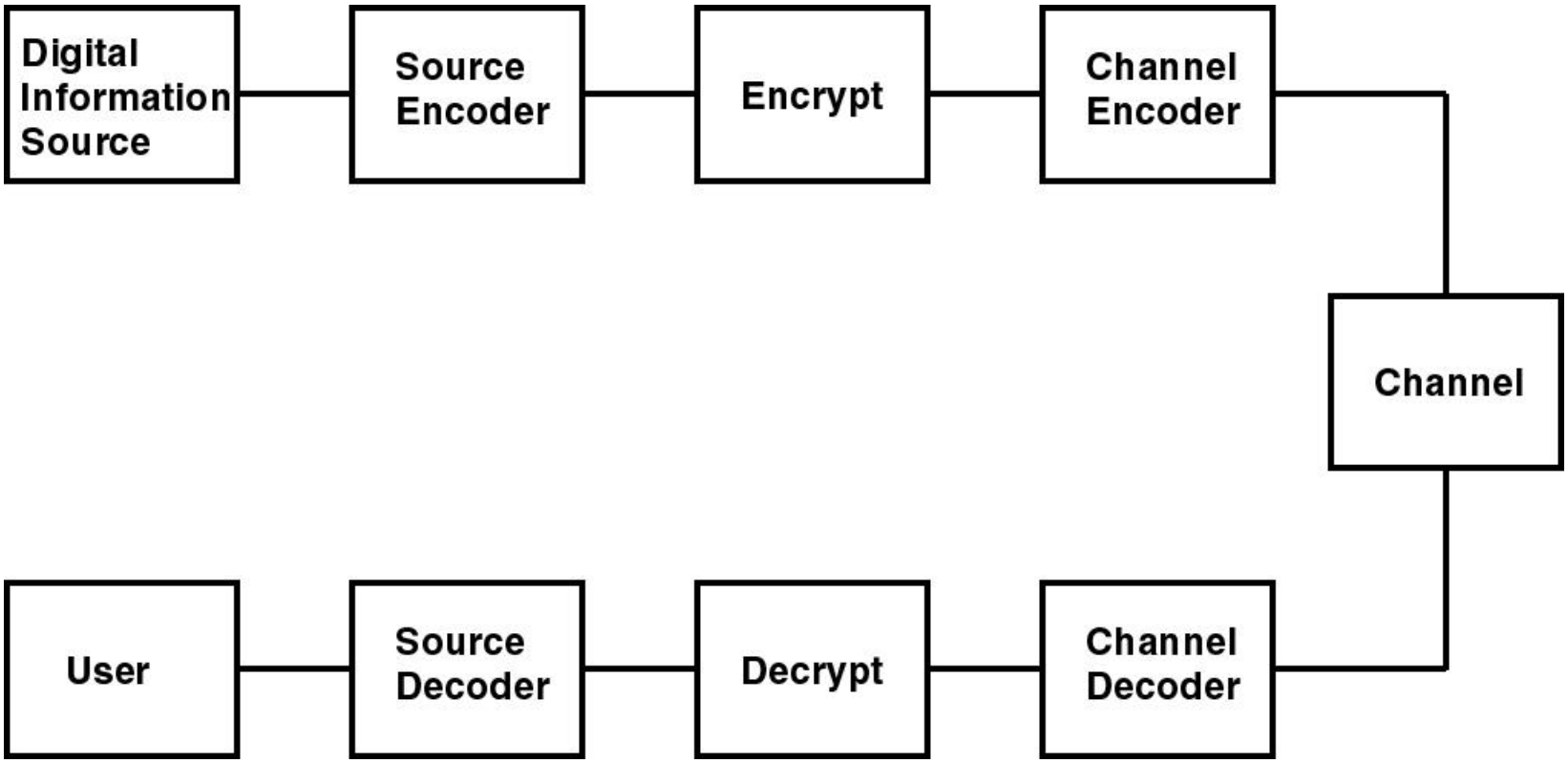
If you do not like the owner of the content or disagree with the way it is distributed, should you steal it?

Digital Millennium Copyright Act

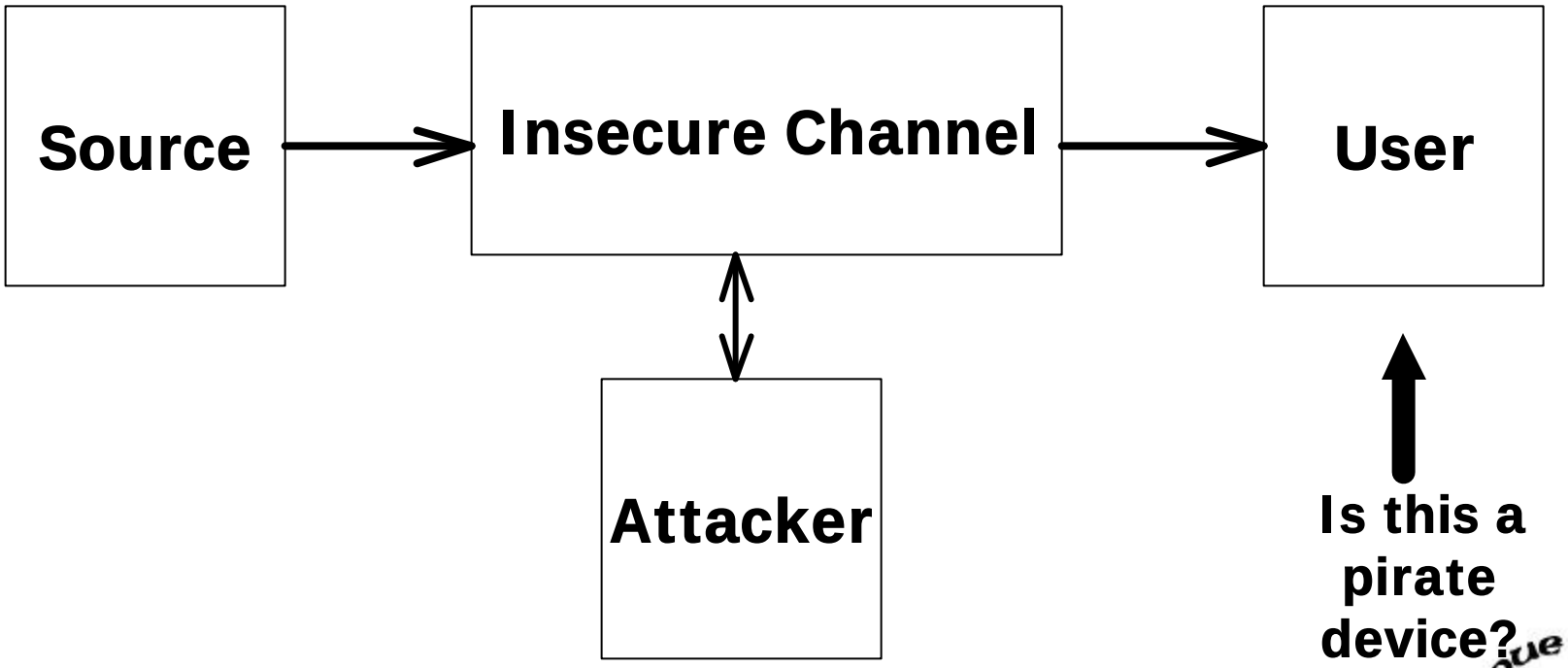
- **Will it be illegal to remove security features from a data element?**
- **Will reverse engineering still be legal?**
- **What constitutes distribution?**
  - **Can I give a data element to my 10,000 closest friends?**

http://lcweb.loc.gov/copyright/

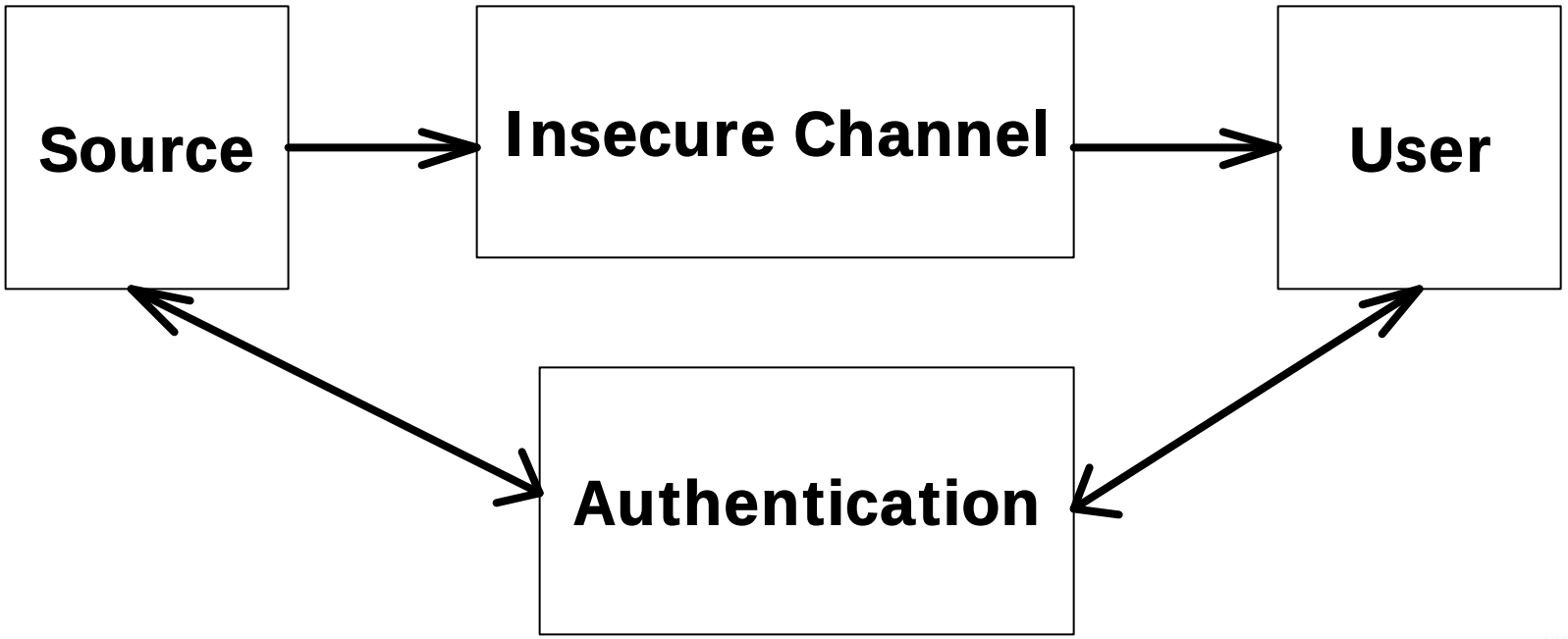
Digital Communication System



Typical Cryptography System: Trusted Users



Cryptography System: User Not Trusted



Media Elements

- **Audio**
- **Video**
- **Documents (including HTML documents)**
- **Images**
- **Graphics**
- **Graphic or Scene Models**
- **Programs (executable code)**

Multimedia Security - Tools Set

- **Encryption**
- **Authentication**
- **Hashing**
- **Time-stamping**
- **Watermarking**

Multimedia Security Applications

- **Privacy**
- **Forgery Detection Þ *watermarking***
- **Copyright Protection Þ *watermarking***
- **Proof of Purchase (non-deniable)**
- **Proof of Delivery (non-deniable)**
- **Intruder Detection**

How do you do this over a noisy wireless channel?

What is Watermarking?

- **The use of perceptually invisible authentication techniques**
  - **– “controlled” distortion is introduced in a multimedia element**
- **Visible watermarks also exists**

Watermarking Scenario

- **Scenario**
  - **an owner places digital images on a network server and wants to "protect" the images**
- **Goals**
  - **verify the owner of a digital image**
  - **detect forgeries of an original image**
  - **identify illegal copies of the image**
  - **prevent unauthorized distribution**

Where are Watermarks Used?

- **Watermarks have been used or proposed in:**
  - **digital cameras**
  - **DVD video**
  - **audio (SDMI Ü *dead on arrival*)**
  - **broadcast video (in US - ATSC)**
    - **visible watermarks now used**
  - **metadata “binding” mechanism**
  - **key distribution systems**
  - **preventing forgery of bank notes**
  - **digital cinema**
  - **“analog hole”**

Steganography

Steganography - (*covered writing*) techniques used to hide information within other information to conceal the very existence of the message

Used much longer than cryptography

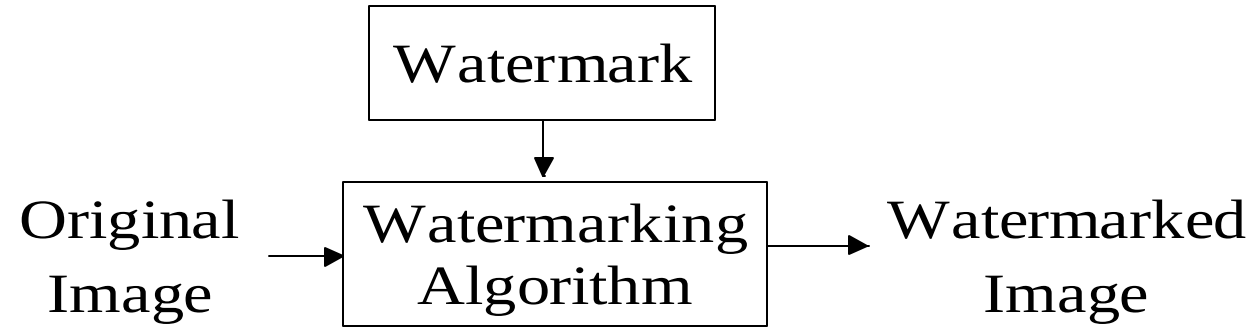
Different than crytography in that an illegal user may intercept the message

Watermarking

- **The use of perceptually invisible authentication techniques is one form of watermarking**
  - **– distortion is introduced in the data**
- **Other forms include visible watermarks**

A Review of Watermarking Techniques

- **Spatial watermarking**
- **Sub-band (wavelet) watermarking**
- **DCT coefficient modulation**
- **Visible watermarks**



Components of a Watermarking Technique

- **The watermark, W**
  - **– each owner has a unique watermark**
- **The marking algorithm**
  - **– incorporates the watermark into the image**
- **Verification algorithm**
  - **– an authentication procedure (determines the integrity / ownership of the image)**

Watermark Detection

- **The tradeoff of detectability vs. visibility (host signal interference)**
- **Do you need the original image for detection?**
  - **– If not Þ blind detection**
- **What about the “key?”**
  - **– private or public?**
- **These are very important when with video**

Main Principles

- **Transparency - the watermark is not visible in the image under typical viewing conditions**

- **Robustness to attacks - the watermark can still be detected after the image has undergone linear and/or nonlinear operations (this may *not* be a good property - *fragile watermarks*)**

- **Capacity - the technique is capable of allowing multiple watermarks to be inserted into the image with each watermark being independently verifiable**

Fragile Watermarks

- **Changes to image easily detected and localized**
- **Used for authentication, rather than copy detection**

Attacks

- **Compression**
- **Filtering**
- **Printing and rescanning**
- **Geometric attacks - cropping, resampling, rotation**
- **Collusion - spatial and temporal**
- **Conversion to analog**

Spread Spectrum DCT Watermark

- **W is a sequence of random numbers**
  - **– bipolar binary sequence, or N(0,1)**
- **X_D and Y_D are DCT of X and Y**
- **a = scaling factor:**

$$Y_D(i) = X_D(i)(1 + aW)$$

DCT Watermark

- **W^* is the extracted version of the watermark**
- **Verification:**

$$S(W, W^*) = \frac{W \cdot W^*}{\sqrt{W^* \cdot W^*}}$$

- **T = user-defined threshold**
- **If S > T, image is authentic**

Original Image

Fixed-length DCT Watermark

a = 0.1

Fixed-length DCT Watermark

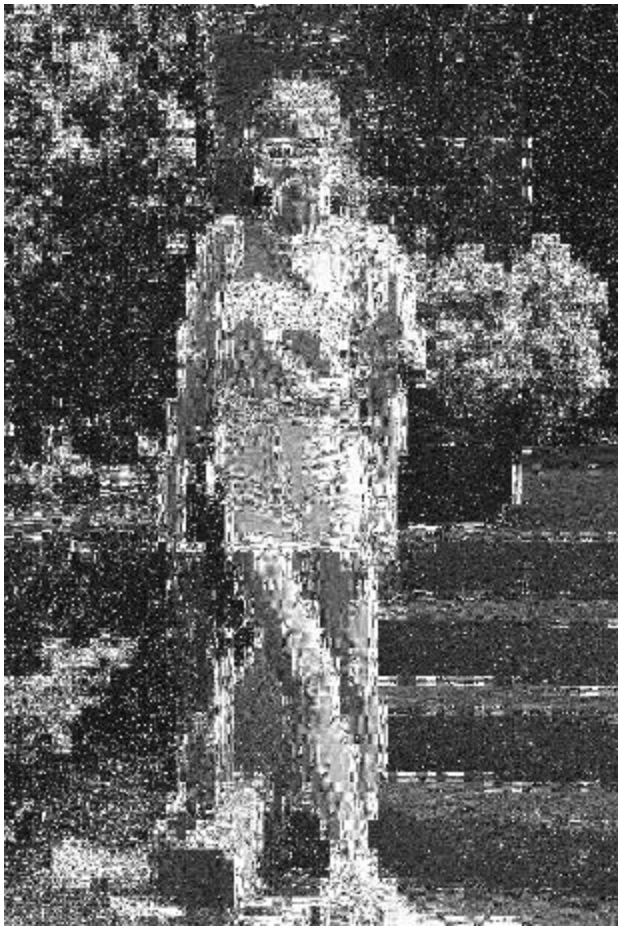
a = 0.5

Fixed-length DCT Watermark

a = 1.0

Fixed-length DCT Watermark

a = 5.0



Digital Image Steganography

- **Example cover and stego images produced by S-Tools 4.0**
  - **Message:** `This is a test message demonstrating the S-Tools 4.0 steganography software.`
  - **Stego key: STEGO**

Cover Image
(8 bits/pixel)

Stego Image
(8 bits/pixel)

Purdue Research Efforts

- **Robust Image-Adaptive Watermarks**
- **Fragile and Semi-Fragile Watermarks for Forensic Imaging**
- **Robust Video Watermarking**
- **Digital Cinema**
- **Watermark Evaluation**
- **Document Protection and Forensic Analysis**
- **Error resilient cryptography**
- **Security in Consumer Electronic Devices and Home Networks**

Image Adaptive Watermarks (DCT)

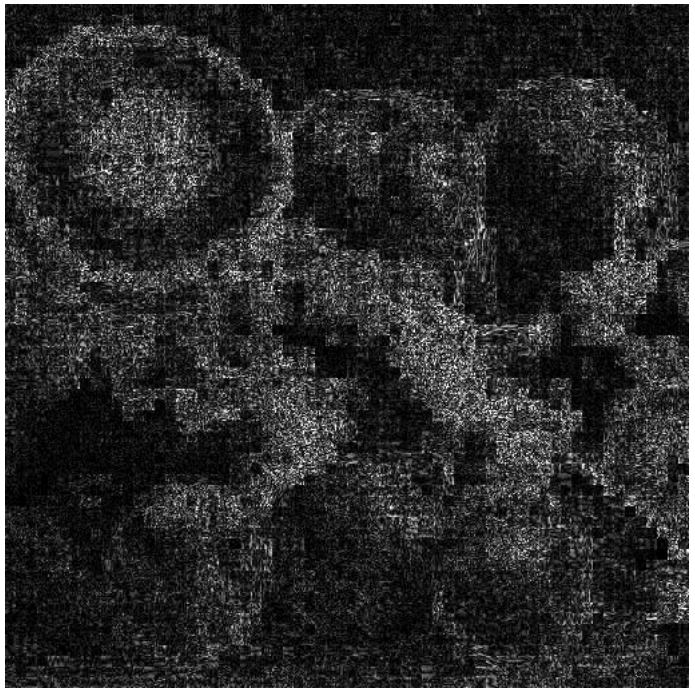
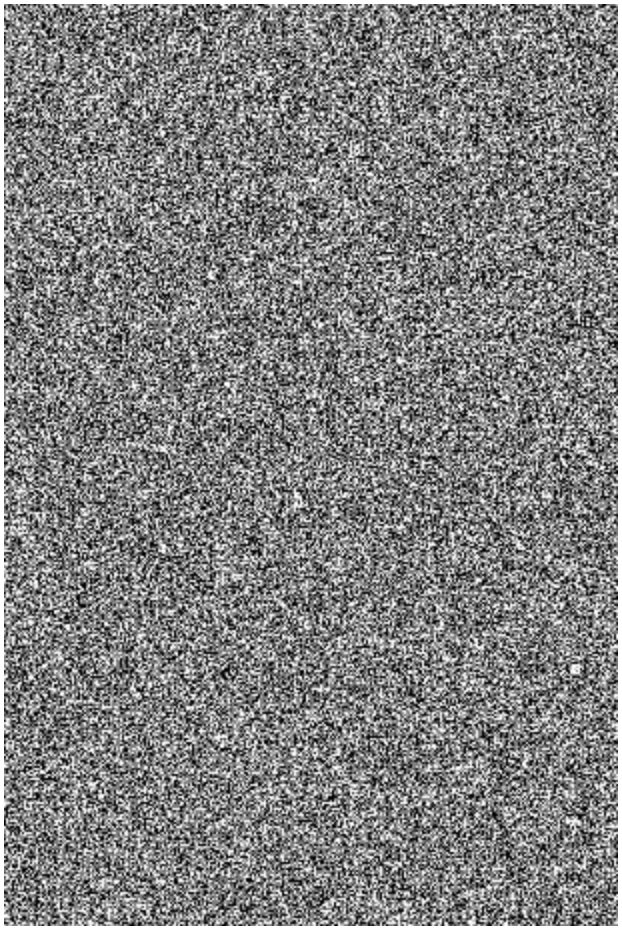


Image Adaptive Watermarks (DCT)

Image Adaptive Watermarks (DCT)

VW2D Watermarked Image

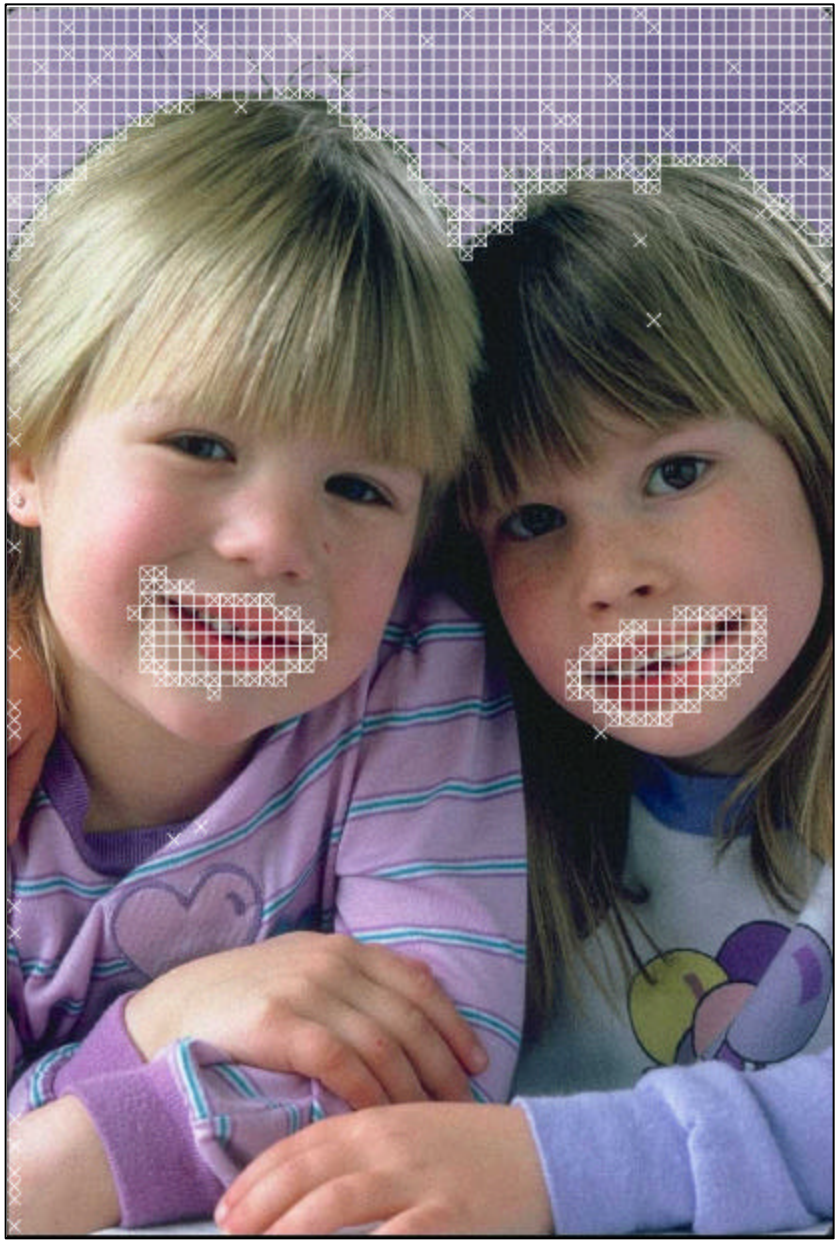
VW2D Difference Image



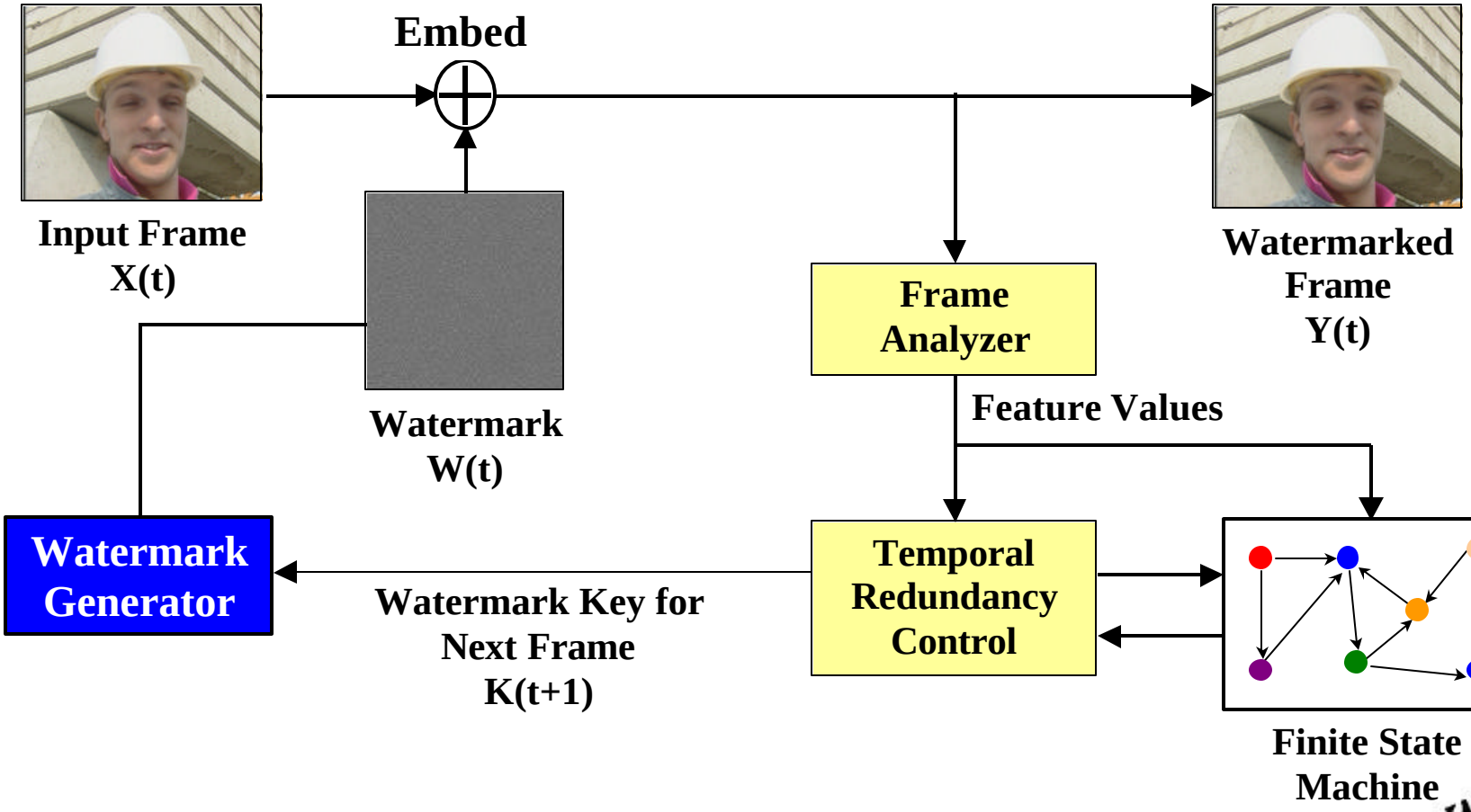
Results - Girls

- Original “Girls”

Altered “Girls” ®



Watermark Embedding Protocol

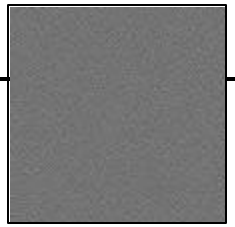


Watermark Detection Protocol

Test Picture
Z(t)

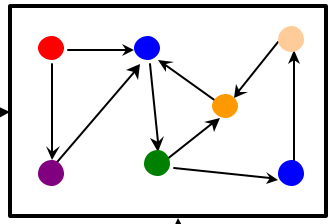
Frame Analyzer

Watermark Detector

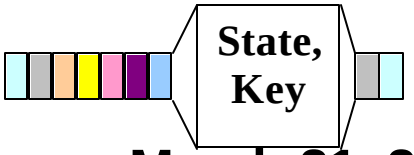


Watermark

Watermark Generator



Memory (Queue)



Conclusions

- **The “secure” multimedia system is evolving**
- **Simple add-ons will not work (not like the text-based systems)**
- **Exploit the unique nature of the type of data**
- **Digital watermarking may be crucial to secure networked multimedia systems**
- **Time stamping is important**
- **New techniques tolerate changes to images, and are compatible with compression**

Conclusions

- **Watermarking is still an interesting research area with many interesting problems**
  - **– where will it be useful?**
  - **– will watermarking only be used a second-tier security system?**
  - **– will there be significant theoretical developments?**
- **Is watermarking the “feel good” technology of multimedia?**