

A Picture's Worth...  
Image Analysis and Forensics

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# Contents

- Digital Image Analysis
  - The Problem with Images
  - Authenticating Images
- Analysis Methods
- Case Study: Dr. Z
- Conclusion





# Disclaimer

- All images and screen shots are copyright by their respective owners and are included for academic discussion and research.
- This complies with the copyright law of the United States as defined and stipulated under Title 17 U. S. Code.
- The methods presented here are experimental.



# Digital Image Analysis



# Pictures Have Power



Space Shuttle Challenger



Iwo Jima, World War II



<http://grin.hq.nasa.gov/IMAGES/SMALL/GPN-2004-00012.jpg>  
<http://www.archives.gov/publications/prologue/2004/winter/top-images.html>  
<http://funny-insurance.blogspot.com/2007/05/top-10-best-funny-photo-of-funny.html>

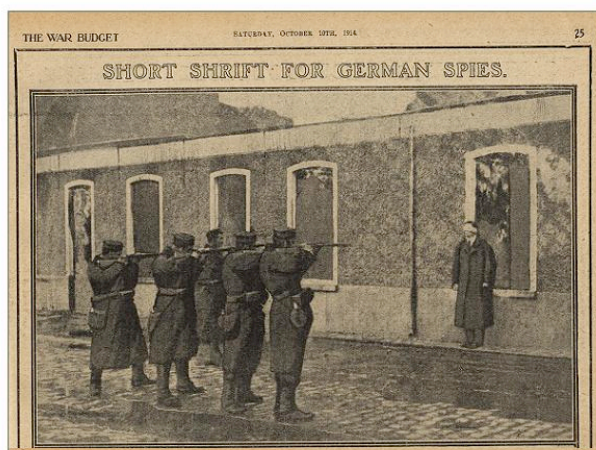


# Not All Pictures Are Real

- Why not real?
  - Modified to influence opinions
  - Enhanced to convey a point
  - Designed to show techniques
- Fake Photos
  - Old School:
    - Staged
    - Mislabeled
  - Hi-tech Methods:
    - Spliced
    - Airbrushed
    - Digitally Modified
    - “Shopped”
- Legal Implications
- Image as Authentication



# Old-School Fakes



10-Oct-1914: "I opened up the paper and what was my surprise to see a big spread picture of myself, lined up against that row of Melle cottages and being shot for the defection of the British public."

Adnan Hajj:  
Beirut (Reuters)  
22 July 2006  
5 August 2006



[http://www.greatwardifferent.com/Great\\_War/Belgium/Belgium\\_War\\_Reporters\\_01.htm](http://www.greatwardifferent.com/Great_War/Belgium/Belgium_War_Reporters_01.htm)  
<http://neveryetmelted.com/?cat=743>

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# Old and New

- Problem
  - Photos are REAL
  - Only identified by close inspection or tracking source
- Combined with new methods



2002 Dust Storm



2004 Tsunami

<http://www.snopes.com/photos/tsunami/sumatra.asp>

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# Images and the Law

- Pornography
  - Protected by the First Amendment
- Child Pornography
  - Child Pornography Prevention Act (1996)
  - Prevents use of children in sexually explicit materials
  - Does not distinguish real from fake
- Virtual Child Pornography
  - Ashcroft v. Free Speech Coalition, 535 U.S. 234 (2002)
  - CPPA violated free speech rights
  - Distinction between “CP” and “VCP”
  - VCP does not use real children (it is regular “pornography”)



# Images as Authentication



419eater.com

has music, sound or strange graphics on it?

6. How do I report Identity theft, Underage User, Cyberbullying, Copyright Violation, to MySpace?

GET STARTED

MySpace.com | Help | SignUp

Find the right buyer for you. [List Now](#)

cars.com

Web | Music | Music Videos | Blogs | Video | Events

Search powered by Google

Invite | Film | Mail | Blog | Favorites | Forum | Groups | Events | Videos | Music | Comedy | Classifieds

with FAQ > **Reporting Abuse** > Someone is pretending to be me - what do I do?

### Someone is pretending to be me - what do I do?

**Solution:**

In order to verify your identity, please send us a "salute":

- This means we will need an image of yourself holding a handwritten sign with the word "MySpace.com" and your Friend ID (your Friend ID number appears immediately after "friendID=" in the web address/URL when viewing your profile). We can then remove the profile that uses your identity without your permission.
- Please be sure to include the web address/URL to the profile in question when you send your salute.
- If the profile is an extremely obvious attempt to be cruel/false, you may not need to send a salute. Sending a salute will help expedite things, though!
- Contact us [here](#).



# My Problem with MySpace



<http://www.peacexpeace.org/elements/images/familysinguy.jfif>





# The Big Questions

- Distinguish “real” from computer graphics
- How to detect image manipulations
- How to pull out information from images
  - Real images: who, where, when, how
  - Digitally enhanced: what, how
  - Computer graphics: what, how



# The Big Answers

- Observation
- Basic Image Enhancements
  - Color Tweaking
- Image Format Analysis
  - Meta Data Analysis
  - Quantization Table Fingerprinting
  - Estimated Compression Level
- Advanced Image Analysis
  - Error Level Analysis
  - Principle Component Analysis
  - Wavelet Transformations



# Observation





# Warez Factory



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# Warez F



Scaled, sharpened,  
enhanced

# Things to Look For

- Time
  - Clocks, calendars
  - Dated materials
- Location
  - Language
  - Region-specific technology
  - Currency and Electrical Outlets!
- Other
  - What's on the computer screen?
  - Any other identifiable elements



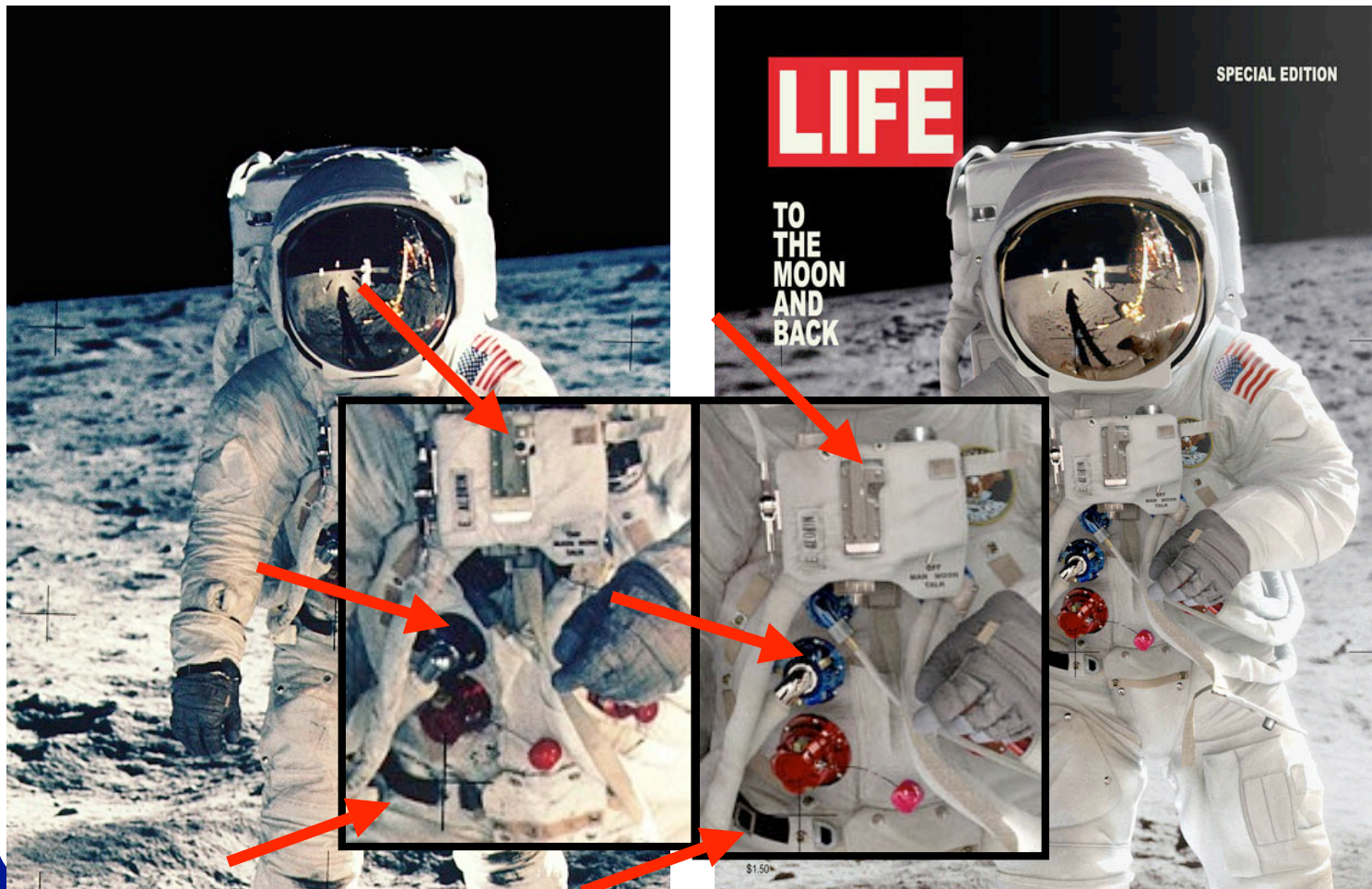


# Example: Buzz

- Andrea Bertaccini
  - [www.tredistudio.com](http://www.tredistudio.com)
  - “CG Choice Award” from CG Society, 2006
- Says based on NASA photo  
<http://www.hq.nasa.gov/office/pao/History/ap11ann/kippsphotos/5903.jpg>



# Example: Buzz Compare



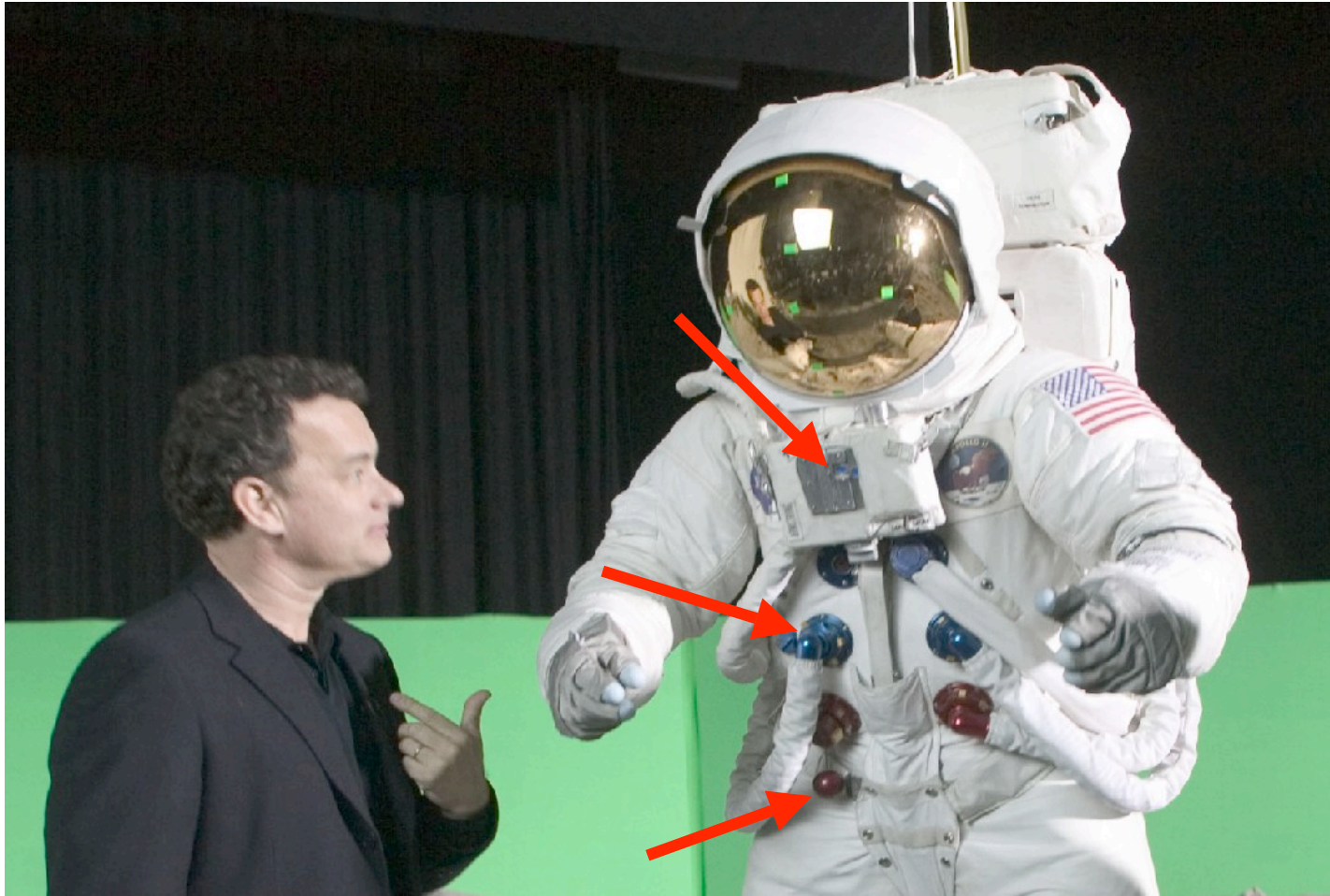


# IMAX: *Magnificent Desolation*

- IMAX recreated moonwalk
  - <http://www.imax.com/magnificentdesolation>
  - Director: Tom Hanks
- Timeframe
  - Movie in 2005
  - Artist image in 2006



# IMAX: *Magnificent Desolation*



# What Happened?

- Artist likely:
  - Modeled position after NASA
  - Modeled spacesuit after IMAX



# Format Analysis



# Image Format Analysis

- Formats *are* information
  - Formats are data that contain data
  - Changes to image yield changes to format
- JPEG as an example
  - Most methods work with any image format



# JPEG Feature Set

- Key Features of JPEG
  - Meta data
  - Quantization matrix for lossy compression
  - Lossy data format
  - Divide image into 8x8 cells
    - JPEG artifacts are usually visible 8x8 cells
- Feature Detection
  - Feature leads to manipulation detection





# JPEG Meta Data

- Information about image
  - Camera type and settings
  - Date and time
- Multiple images
  - Varying quality
  - Useful for distinguishing cameras
- Meta data problem:
  - Modified or inaccurate
  - Applications do not update meta data!
    - Photoshop keeps camera info (even if picture changes)
    - Photoshop does not log Photoshop changes

```
$ exiftool IM001022.JPG
MIME Type           : image/jpeg
JFIF Version        : 1.1
Make                : Hewlett-Packard
Camera Model Name   : HP PhotoSmart 618
Orientation         : Horizontal (normal)
X Resolution        : 72
Y Resolution        : 72
Resolution Unit     : inches
Y Cb Cr Positioning : Centered
Exposure Time       : 1/125
F Number            : 3.7
ISO                 : 100
Exif Version        : 0210
Date/Time Original  : 2007:05:28 09:19:49
Components Configuration : YCbCr
Compressed Bits Per Pixel : 1.6
Shutter Speed Value : 1/128
Aperture Value      : 4.0
Exposure Compensation : 0
Max Aperture Value  : 4.0
Subject Distance    : 0.13 m
...
```



# Quantization Fingerprinting

- Should compute optimal quantization tables
  - CPU intensive!
  - Slow user experience!
- Hard-coded quantization tables
  - Few systems actually generate Q tables
  - Digital cameras use different Q tables
    - Vary by make and model
    - Optimized for CCD, data size, manufacturer
    - Canon pictures look best on Canon printers (colors optimized)
  - Cannot just “copy over” Q tables
- Forensics
  - Match Q tables to application or camera
    - Media outlets: Pay attention!



# Quantization Quality

- What if Q tables not known?
- JPEG uses a quality value
  - Save at 95%, 80%, 65%...
  - Quality corresponds with size
- Quality not saved in JPEG!
  - Fingerprint Q table? Know tool and quality
  - Unknown Q table? Need to determine quality
- Derive quality value!



# Quantization Tables

- Q tables: compression and quality
- Two tables for YCrCb
  - 1 for luminance (Y)
  - 1 for both Cr and Cb
  - Optional:
    - 3 tables: Y, Cr, and Cb
- 64 elements
  - 1st element = DC
  - 63 elements = AC
    - Compression by frequency

# Quantization table

# Table index=0 (luminance)

3	2	2	3	2	2	3	3
3	3	4	3	3	4	5	8
5	5	4	4	5	10	7	7
6	8	12	10	12	12	11	10
11	11	13	14	18	16	13	14
17	14	11	11	16	22	16	17
19	20	21	21	21	12	15	23
24	22	20	24	18	20	21	20

# Quantization table

# Table index=1 (chrominance)

3	4	4	5	4	5	9	5
5	9	20	13	11	13	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20



# Example Derivation

- Average AC values
  - Table 0: 11.63
  - Table 1: 17.57
- Average Y, Cr, Cb
 
$$(11.63 + 17.57 + 17.57) / 3 = 15.59$$
- Get RGB/YCrCb conversion
 
$$||17.57 - 11.63|| = 5.94 \text{ convert}$$
- Combine to find quality
 
$$100.0 - 15.59 + 9.65 = 90.35\%$$

Call it 90%

# Quantization table

# Table index=0 (luminance)

3	2	2	3	2	2	3	3
3	3	4	3	3	4	5	8
5	5	4	4	5	10	7	7
6	8	12	10	12	12	11	10
11	11	13	14	18	16	13	14
17	14	11	11	16	22	16	17
19	20	21	21	21	12	15	23
24	22	20	24	18	20	21	20

# Quantization table

# Table index=1 (chrominance)

3	4	4	5	4	5	9	5
5	9	20	13	11	13	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20



# Quantifiable Problem

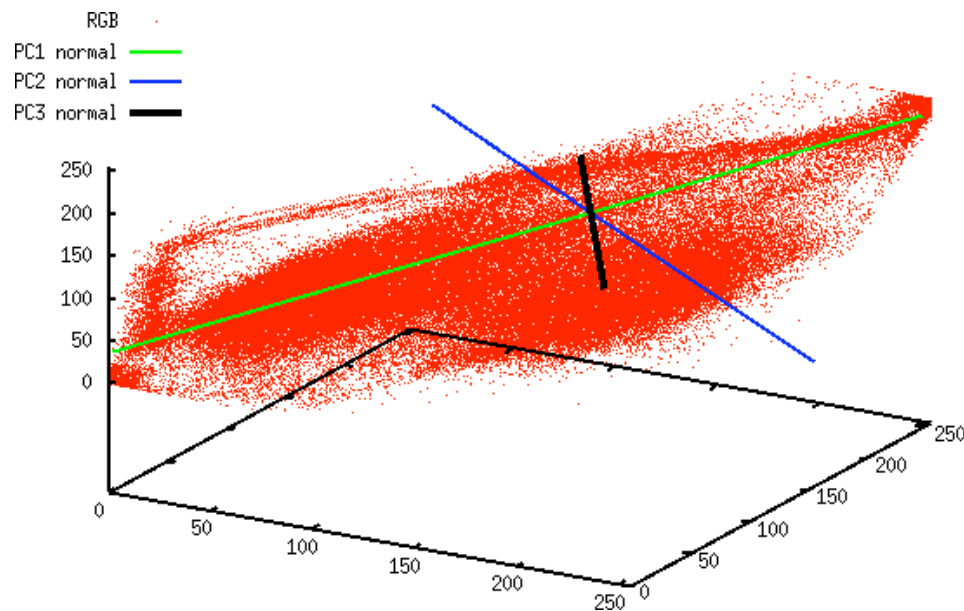
- Data loss is cumulative
- Resave problem:
  - Save an image at quality of 75%
  - Resave image at 90%
  - Image does *not* get better!
    - $90\% \text{ of } 75\% = 67.5\%$
  - Quantization tables reflect 90%, not 75% or 67.5%
- How to detect image resaves?
  - Principal Component Analysis!



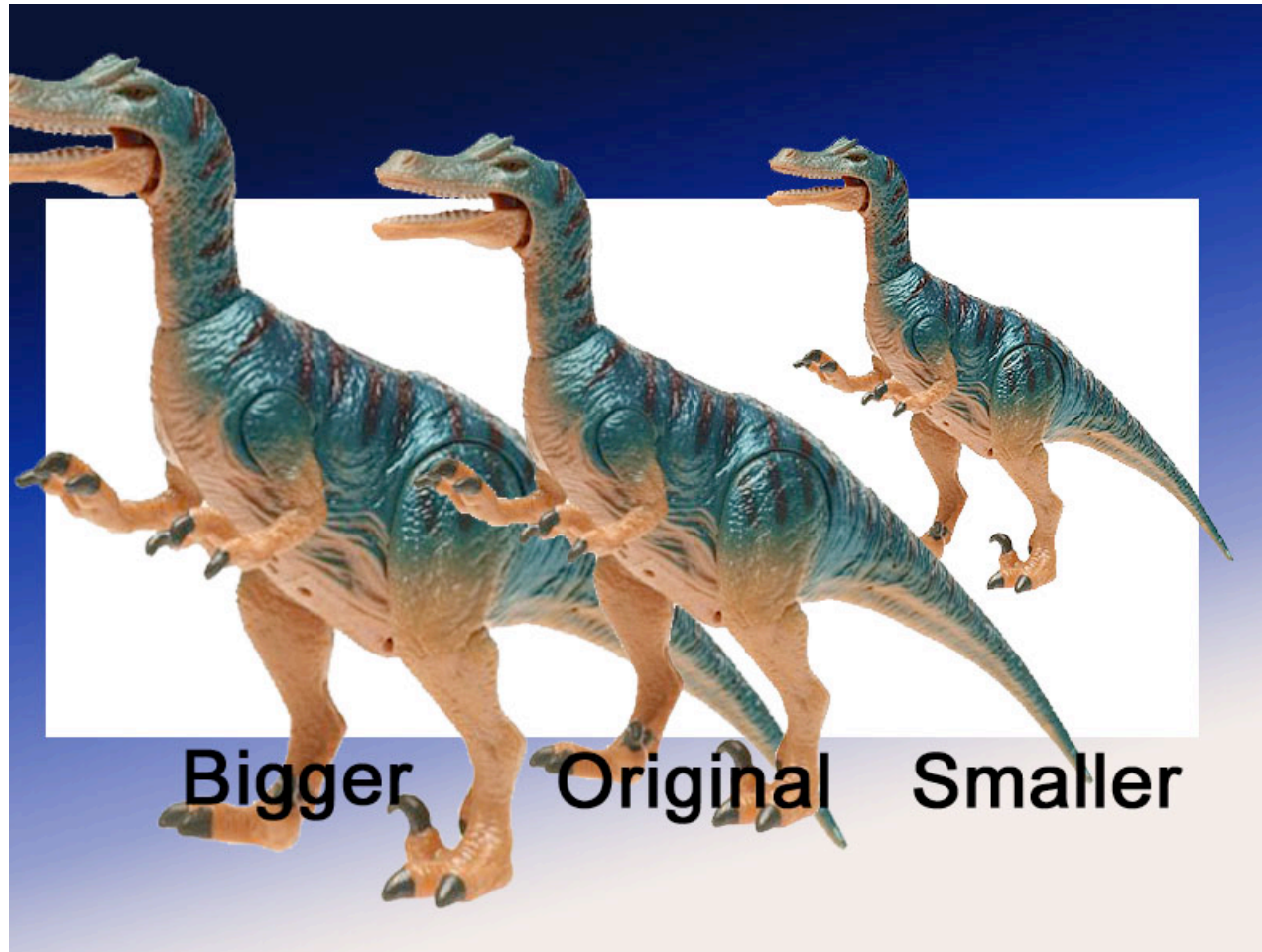


# Principal Component Analysis

- PCA separates info
  - Computer vision
  - Data compression
- Identifies widest variance among points
  - 3D = 3 components
  - PC1 = widest
  - PC2 = next widest
  - PC3 = narrowest

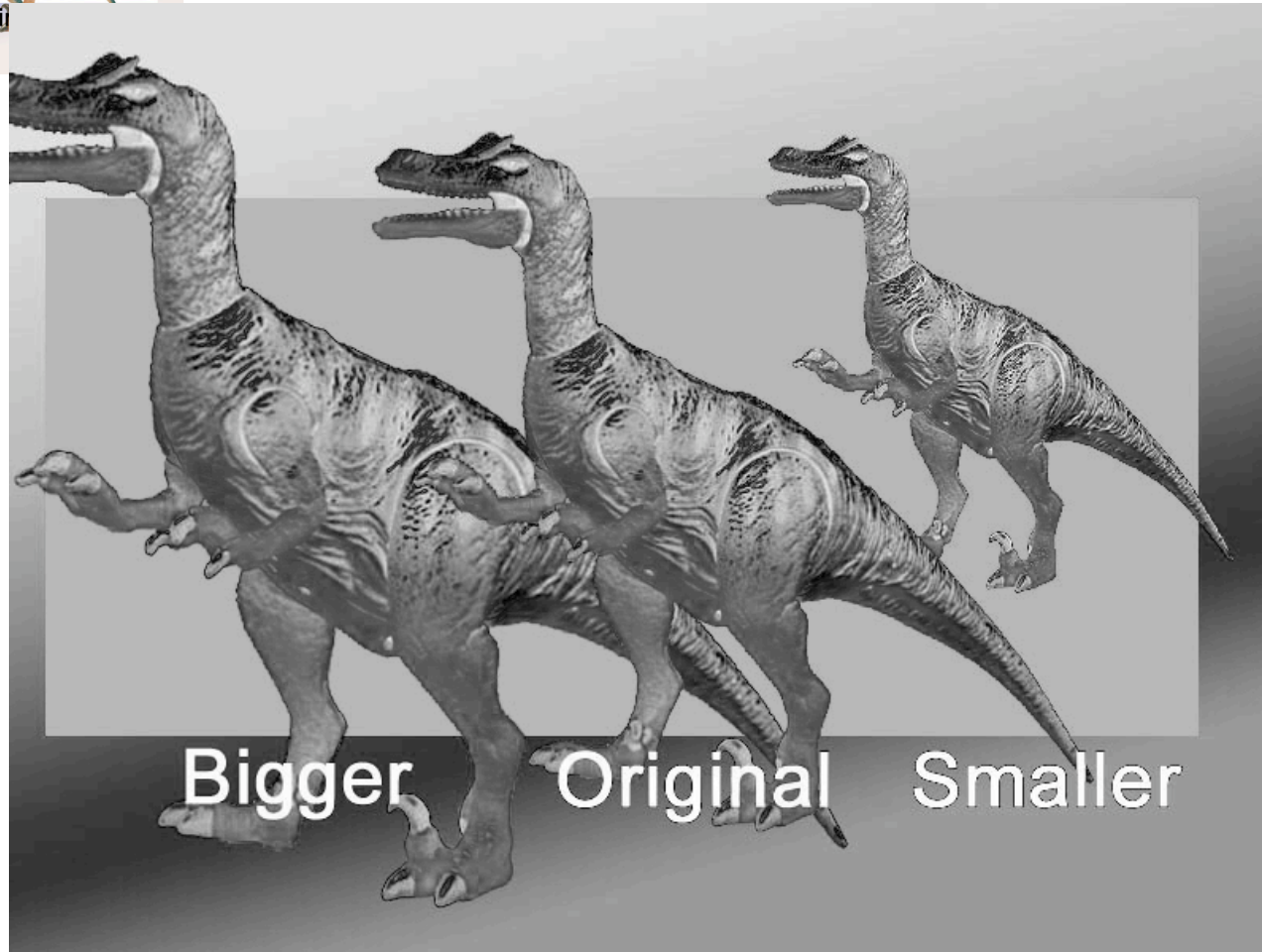


# PCA Example





# PCA Example

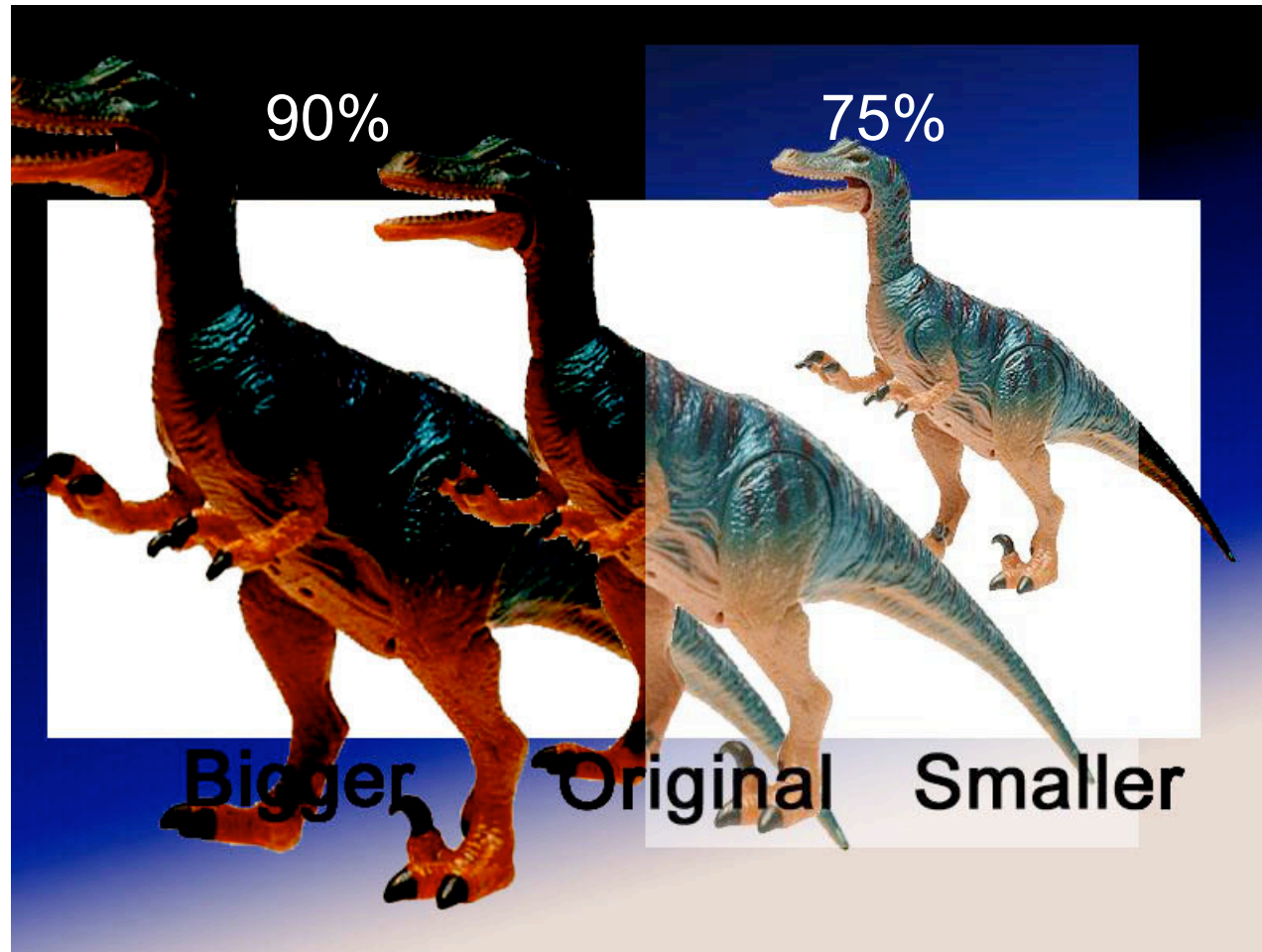


# PC1 with Artifacts

95%  
90%  
80%  
70%  
60%  
**50%**

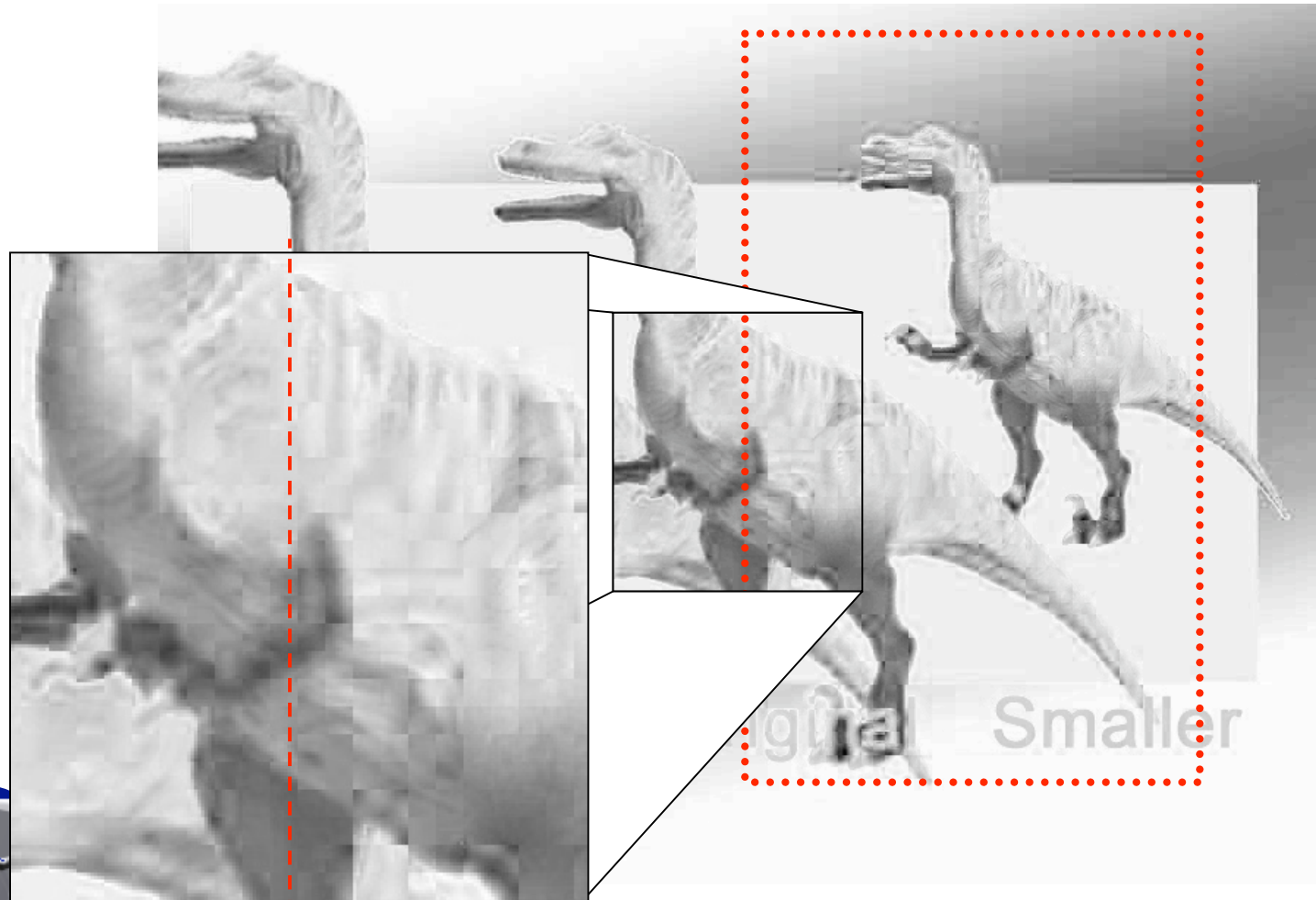


# PCA Mixing: 90% with 75%





# PCA Mixing: 90% with 75%





# Example: Back to the Moon



# Buzz Aldrin Moon Walk

- “All the image are made in 3DS MAX and postprocessed in Combustion and Photoshop.”

<http://forums.cgsociety.org/showthread.php?t=323480>

- JPEG Q tables say:
  - Photoshop
  - 89% quality



# Buzz Aldrin Moon Walk



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# Walk

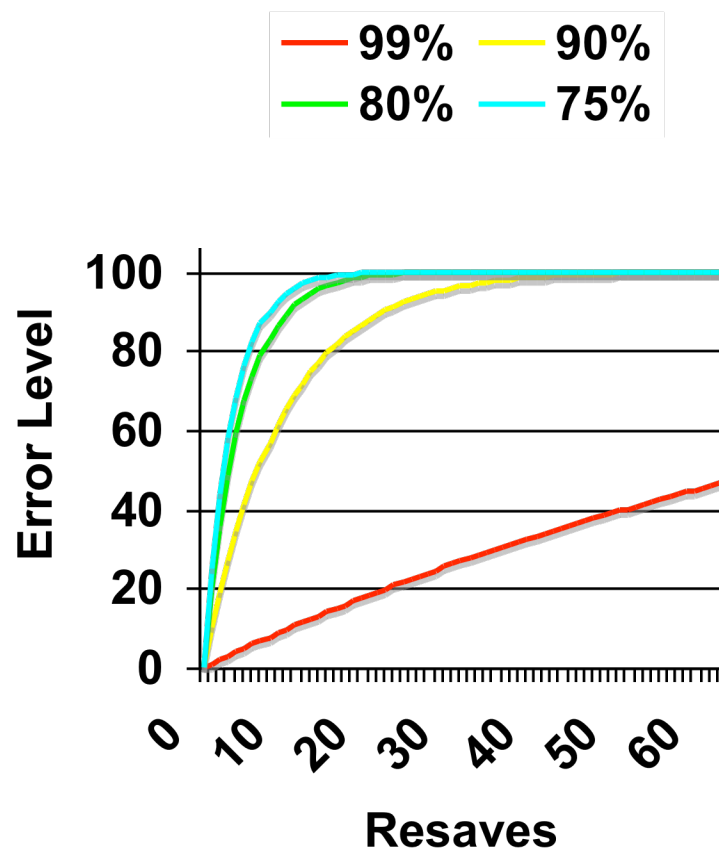


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# Error Level Methodology

- JPEG is lossy format
- Each resave introduces more error
  - But “copy” does not
- Error rate not linear!



# Error Level Analysis

- Each 8x8 cell should be at same quality level
- Changes to image change quality level for the 8x8 cell

## Methodology

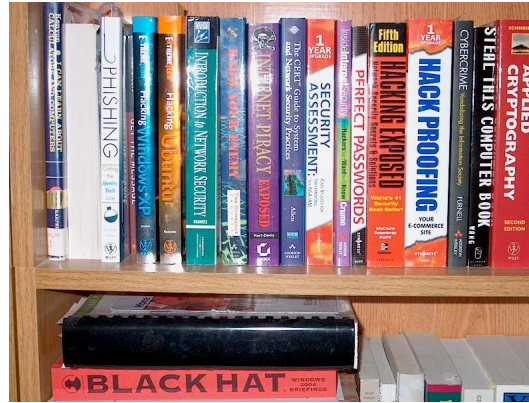
- Save image at 95%
  - Intentionally introduce known error rate
- Compare original and new 95% image
- Difference = error state
  - No difference = image local minima
  - Large difference = unstable 8x8 cell = original pixels!



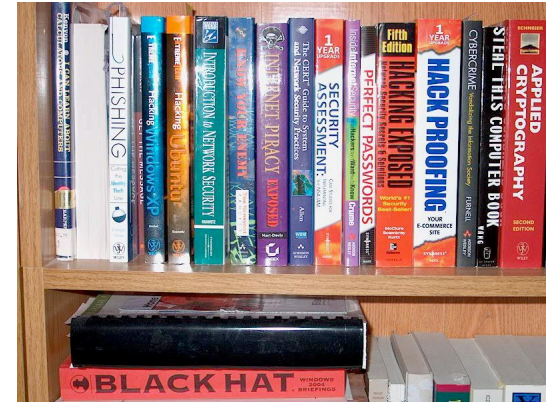
# Error Rate Example



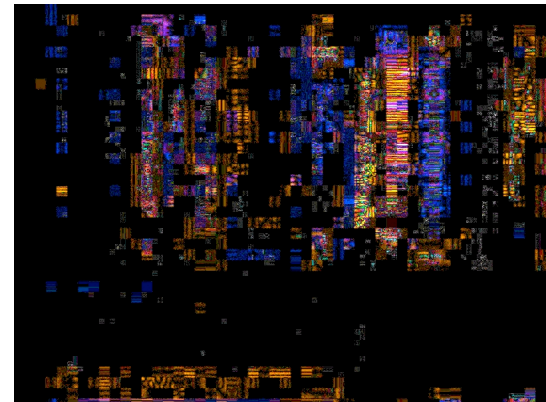
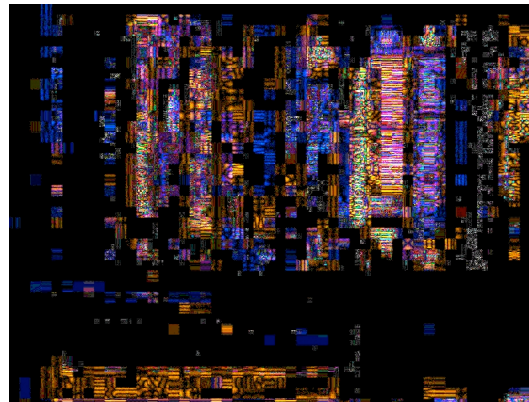
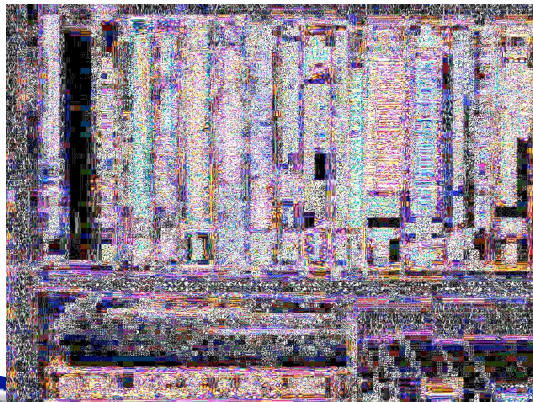
Original



Resave #1, 75%



Resave #2, 75%





# Modification Detection



Resave #1, 75%



Edited: Books, Dinosaur



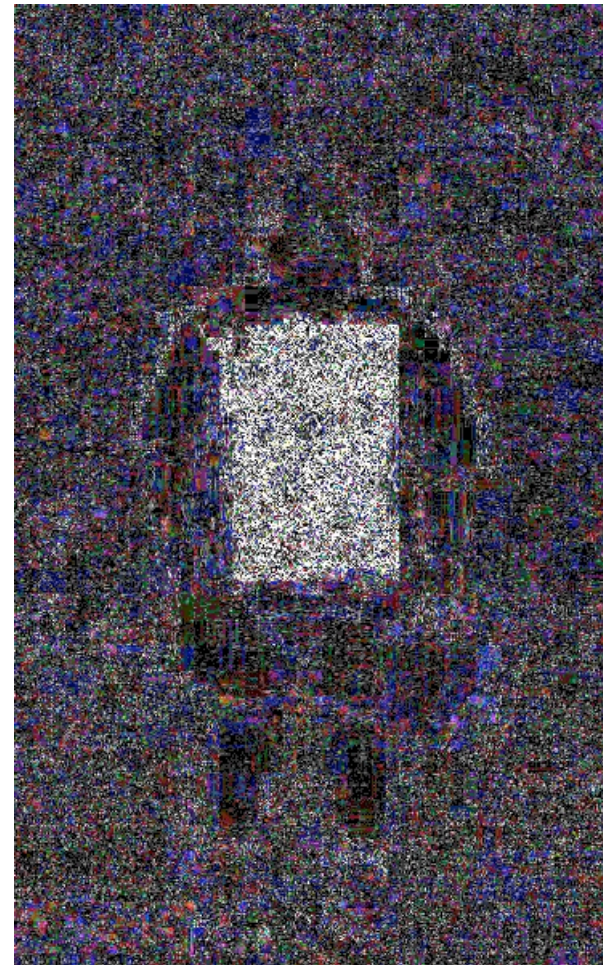


# The “Alf Kid”!

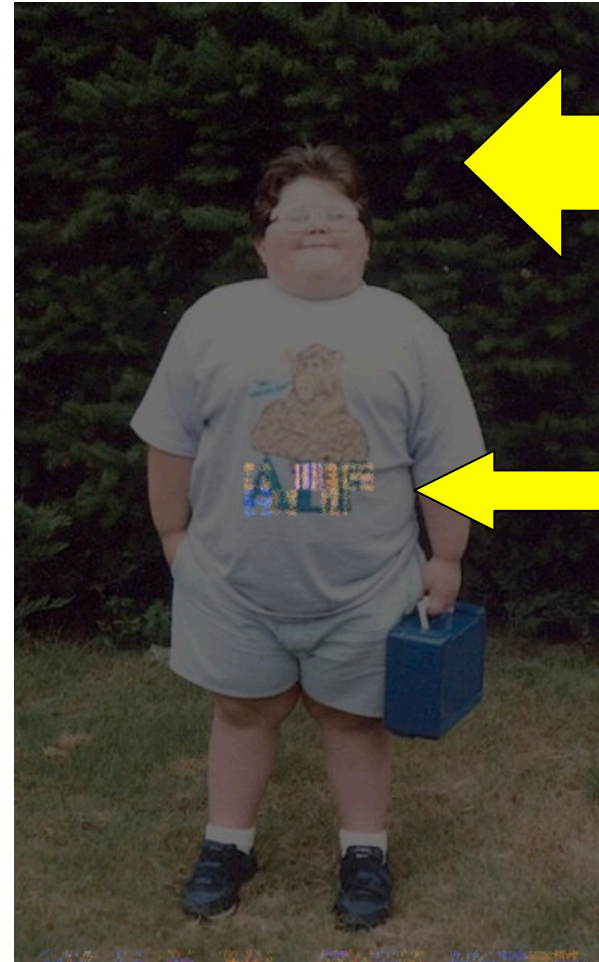




# “Alf Kid” Error Level Analysis



# Original “Alf Kid”?



Multiple  
resaves

?

Cropped

48

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# Crash Modifications



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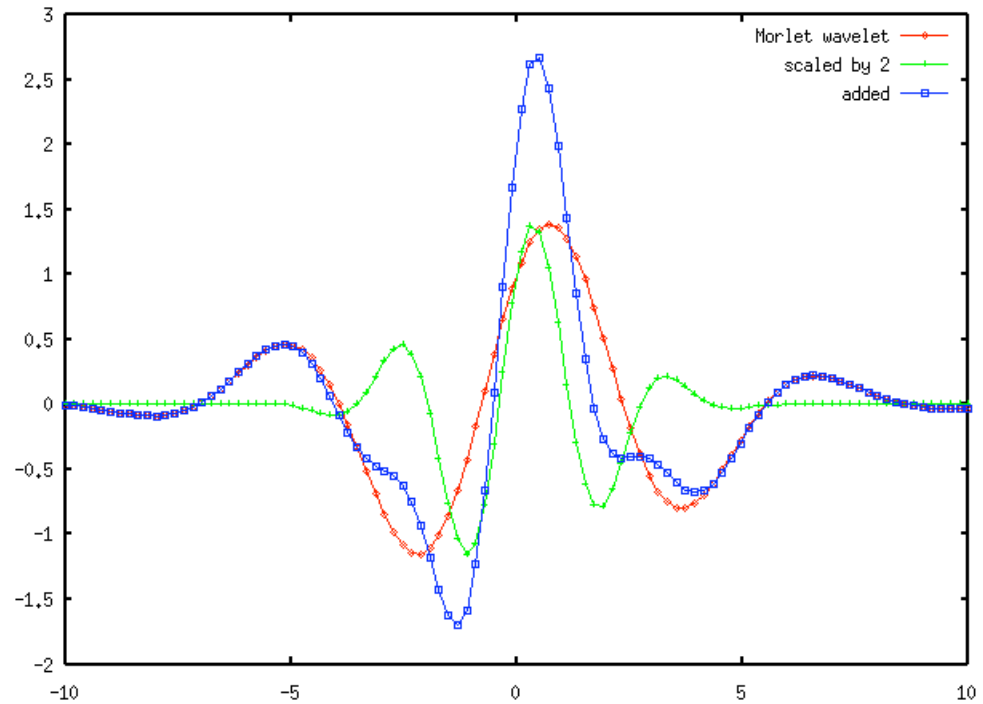
# Crash Modifications



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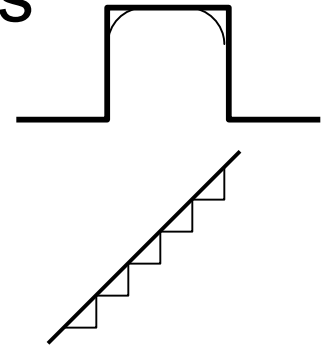
# Wavelet Transformations

- Problem:
  - If quality is same, how can you find differences?
  - How to identify layers?
- Solution?
  - WAVELETS!



# Wavelet Limitations

- Any signal can be approximated
- Some signals more difficult than others
  - Square waves or sharp color changes
  - Smooth, linear transitions
  - Extreme values (black or white)
- Some signals easier to approximate
  - “Natural” colors
  - Noisy images (e.g., CCDs)



# Wavelet Image Analysis

- An 800x600 picture has 480,000 wavelets
  - Render only a few % to get general picture
    - Picture will appear blurry
  - Entire image should sharpen at same rate
- Image modification detection
  - Scaled images sharpen at different rates
  - Images from different focal lengths sharpen at different rates
  - Why? Images have different signal patterns





# Wavelet Example

Original

1%

2%

3%

5%

8%

10%

20%

30%

40%





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& EASY  
IDEAS  
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Age

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MAKEUP  
BUYS & TIPS

WHY  
BILL IS  
BACK

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www.harpersbazaar.com

# Analysis Limitations

- Small Images
  - Wavelets fail
- Scaled Images
- Low Quality
  - Image Corruption
  - GIF and limited-color images
- Wavelets and harmonics
- Mixing Media
  - From Photo to Magazine to JPEG...
- Extremely Talented Artists (rare)



# Case Study: Dr. Z

Dr. Ayman al-Zawahiri  
#2 guy in Al Qaeda



# USA Today

USA TODAY

Home News Travel Money Sports Life Tech W

World Inside News Buy

## Al-Zawahri: U.S. is talking to wrong people in Iraq

Updated 12/20/2006 8:13 AM ET



CAIRO (AP) — al-Zawahri, the leader of al-Qaeda, is negotiating a video broadcast, according to a U.S. government contractor IntelCenter, talking to his followers.

"I want to tell you that you are trying to force withdrawal, and your attention is on the tape, and the bulletins."

"It seems that you will go through a painful journey of failed negotiations until you will be forced to return to negotiate with the real powers," he said, without identifying these powers.

The video — which bore the logo of al-Qaeda's media production house, al-Sahab — was the 15th time this year that al-Zawahiri has sent out a statement. In Wednesday's tape, he appeared exactly as in previous videos that have been authenticated by CIA analysts. He wore a black turban and white robe and pointed his finger at the camera for emphasis. As usual, he had a rifle behind his right shoulder that was leaning against a plain brown backdrop.

The last al-Qaeda video distributed by U.S. government contractor IntelCenter shows Ayman al-Zawahiri in a video, which was released in September 2006.

Enlarge AP

“He wore a black turban and white robe ... he had a rifle behind his right shoulder that was leaning against a plain brown backdrop.”





# USA Today Picture



“He wore a black turban and white robe ... he had a rifle behind his right shoulder that was leaning against a plain brown backdrop.”



# USA Today Picture



28-Sept-2006

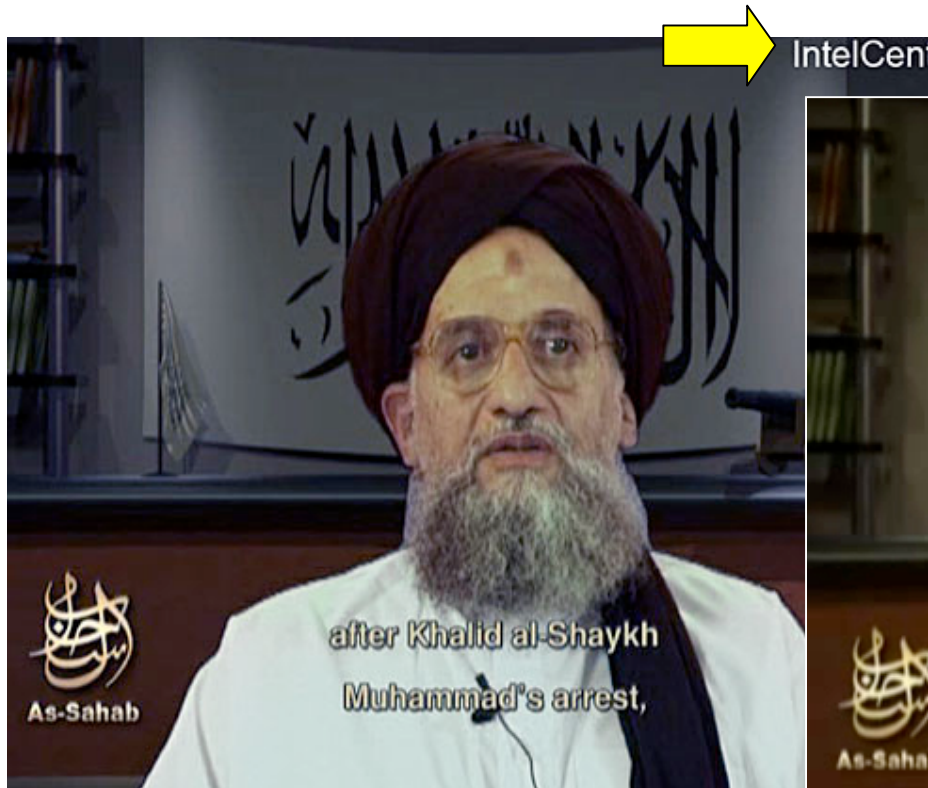


20-Dec-2006





# USA Today Picture



IntelCenter



# What Else Added?



IntelCenter

## Last Things Added:

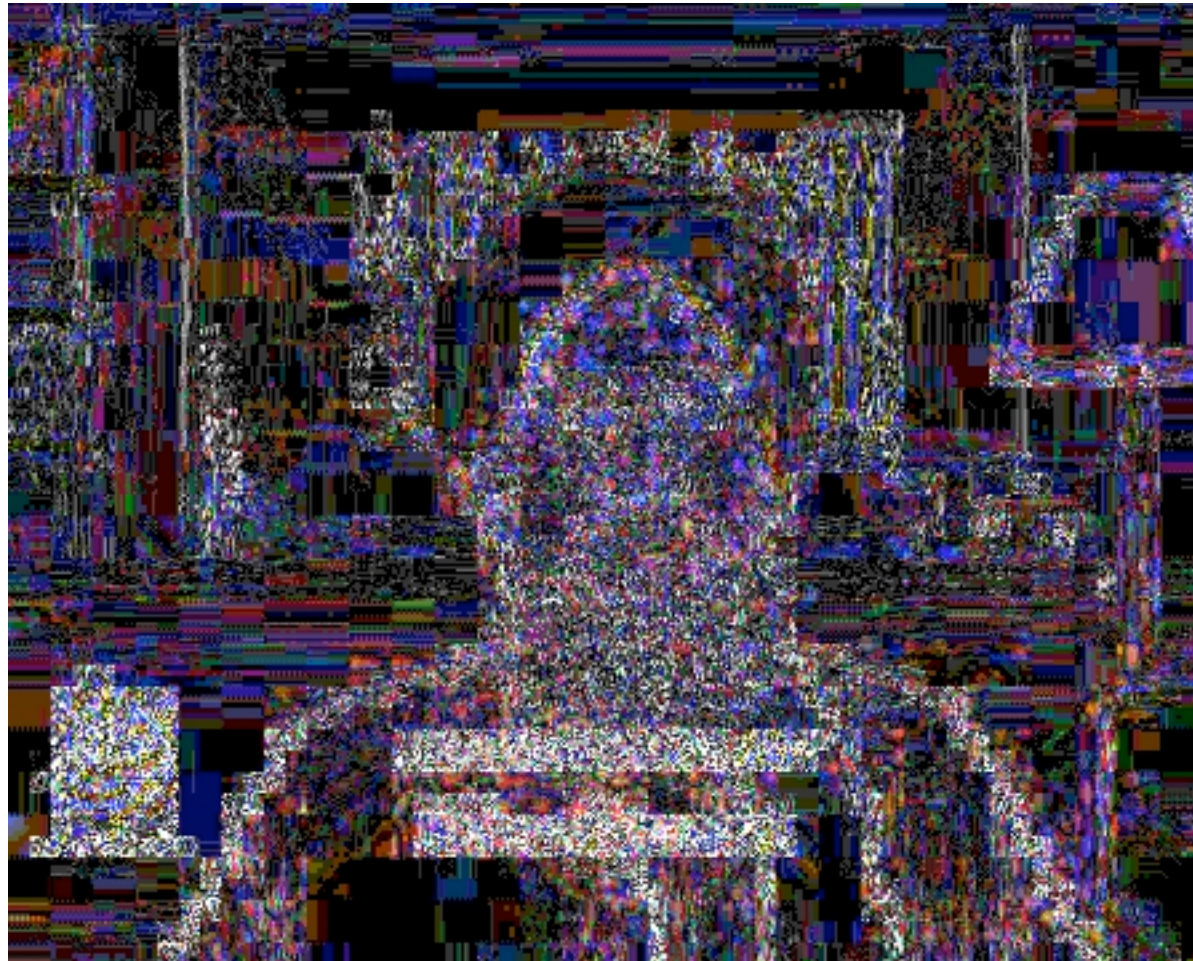
- Image Cropped
  - Observed, to 8x8 grid
- “IntelCenter”
- Subtitles & Logo
- Al-Zawahiri!
  - Outline = chroma key
- Banner text!





# And in the Original?

Original  
Error  
PCA  
Wavelet  
5%



# What About Other Videos?



27-July-2006

Zawahiri Video Speech Regarding Lebanon and Gaza

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# Analysis: Error Level and PC1

Error  
PCA

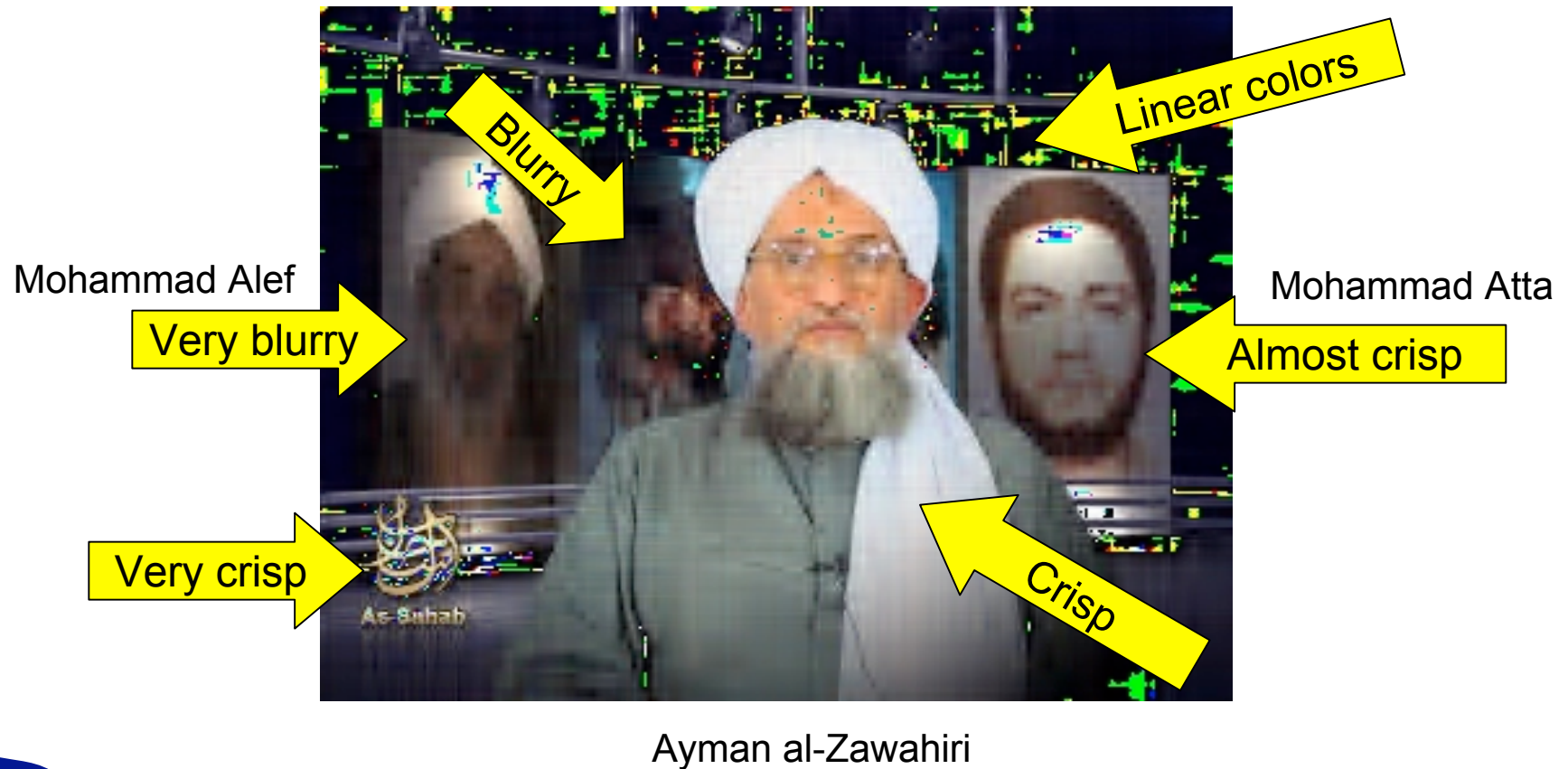




# Analysis: PC3!



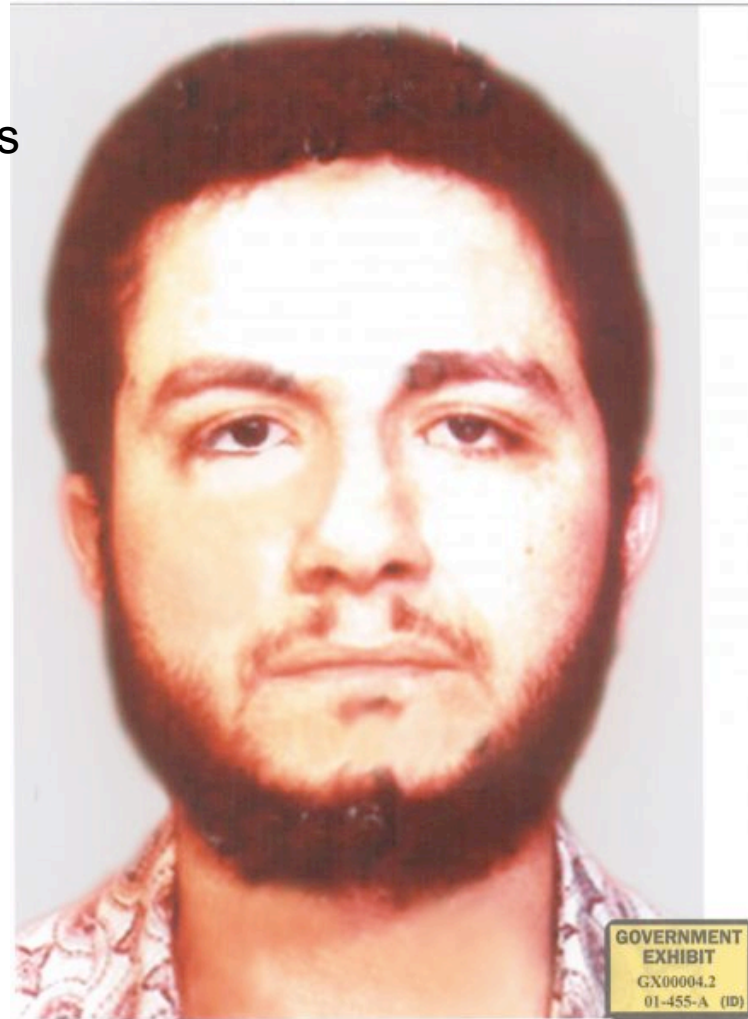
# Wavelets 5%: 6 Layers!



# Mohammad Atta

Made in Layers

Identify any  
sources?



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# SITE Seeing

- *Saying* that there is a green screen is **not** the same as *seeing* the green screen
- SITE Institute ([www.siteinstitute.org](http://www.siteinstitute.org))
  - 22-Jan-2007: Intercepted Al Qaeda video!
  - 25-Jan-2007: Video released by Al Qaeda

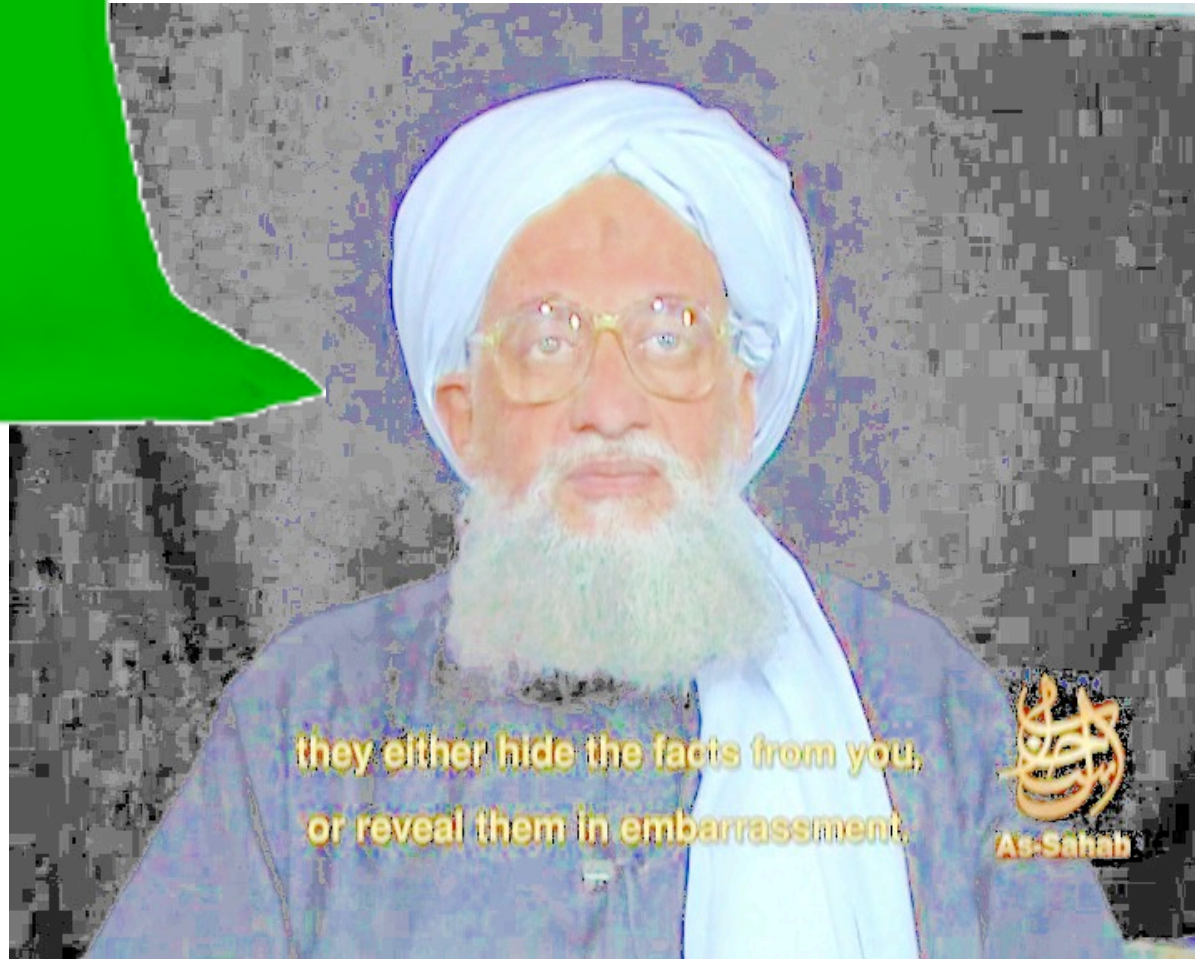
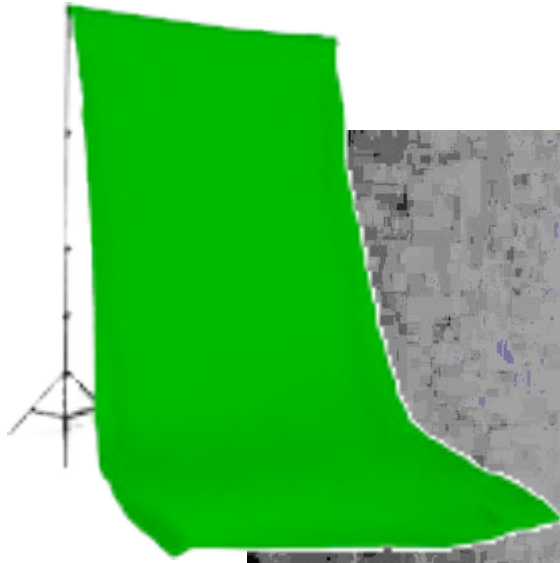




# Back in Black



# Lighting



# Green Screen Fun



they either hide the facts from you,  
or reveal them in embarrassment.





# Green Screen Fun





# Green Screen Fun

PC1



# Azzam al-Amriki



2-Sept-2006

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75



# Azzam al-Amriki



Logo

Books?

2-Sept-2006

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# Azzam al-Amriki



Logo

Books?

2-Sept-2006

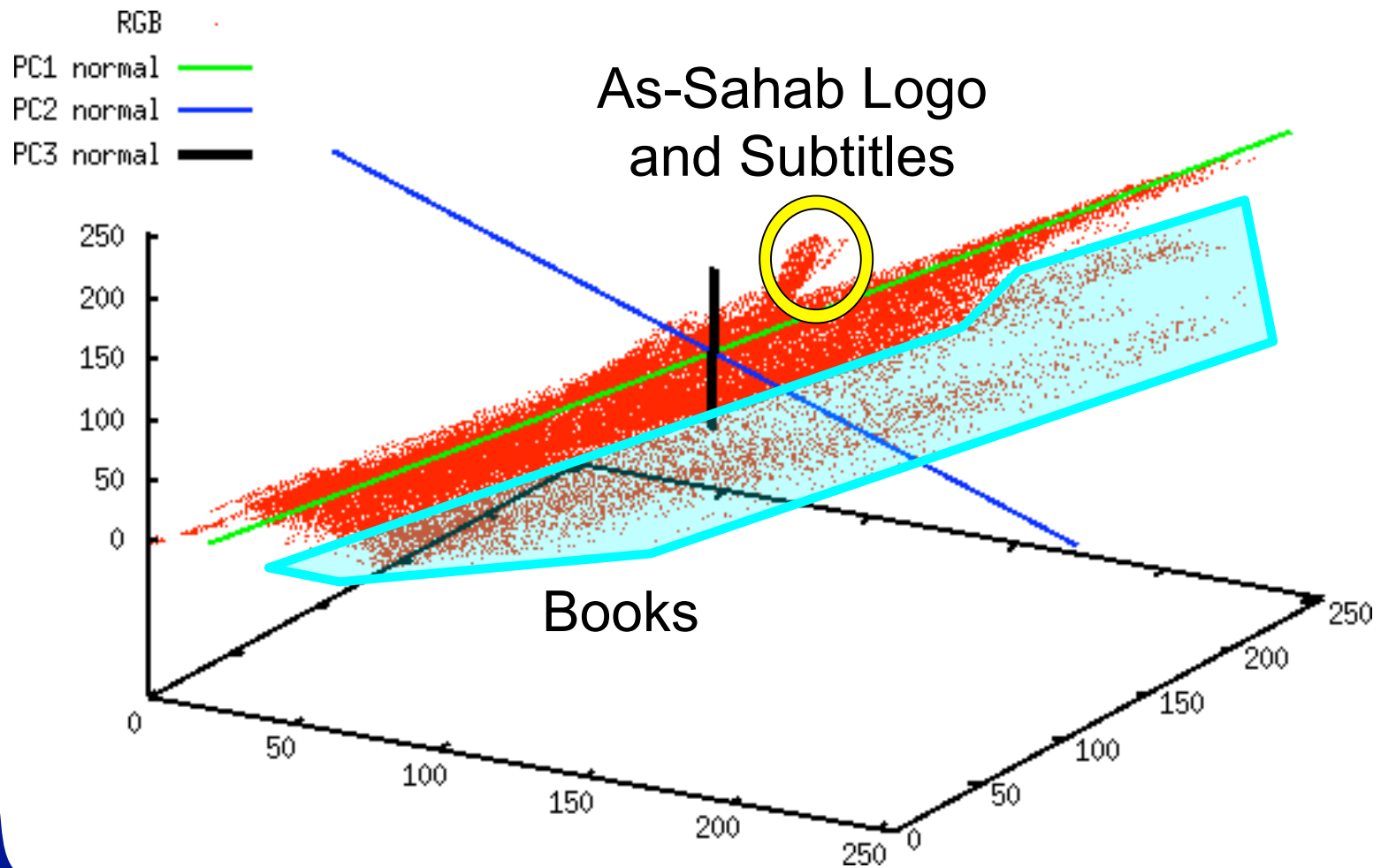
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# Color Graph



# Conclusion



# Need for Image Analysis

- Real versus Computer Generated
- If Modified, How?
- Uses
  - Media: Reality vs Fiction
  - Legal: Child Pornography vs VCP
  - Authentication: Real vs Doctored



# Methods Covered

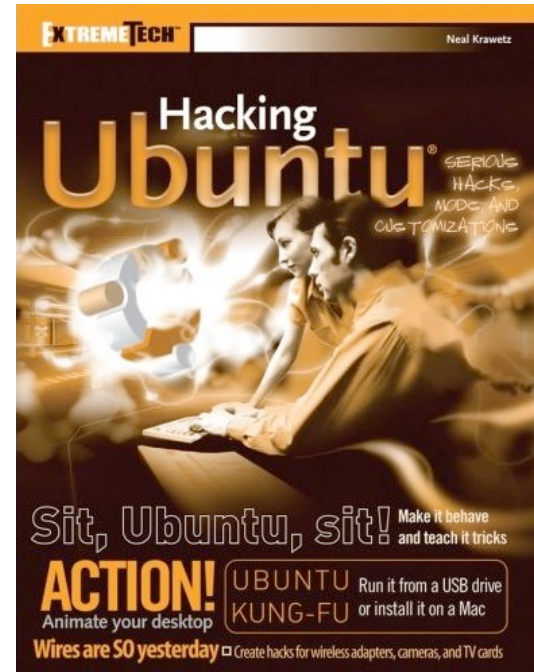
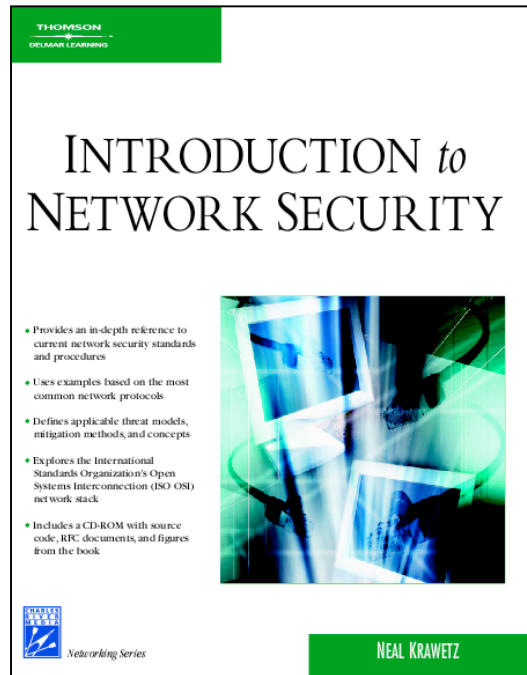
- Observation
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# Questions?

Shameless self-promotion.



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Hacker Factor Solutions  
[www.hackerfactor.com](http://www.hackerfactor.com)

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