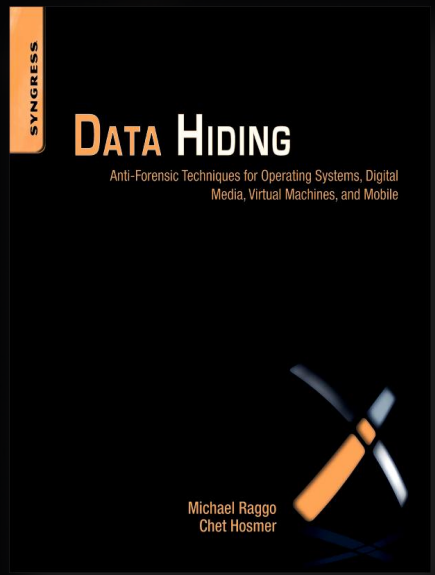
A Picture is Worth a Thousand Words, Literally:

Deep Neural Networks for Social Stego

Philip Tully | Mike Raggo

#whoami



Philip Tully
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Mike Raggo
@datahiding

ZEROFOX®

802secure

Principal Data Scientist at ZeroFOX

PhD (KTH & University of Edinburgh)

Machine Learning and Neural Nets

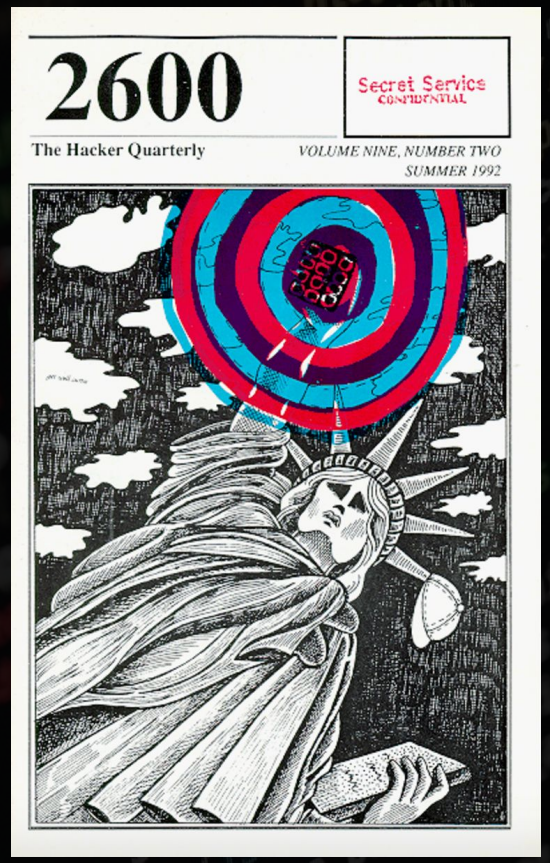
CSO @802 Secure, 17 yrs Stego Research

StegSpy DC12, Author “Data Hiding”

NSA National Cryptologic Museum

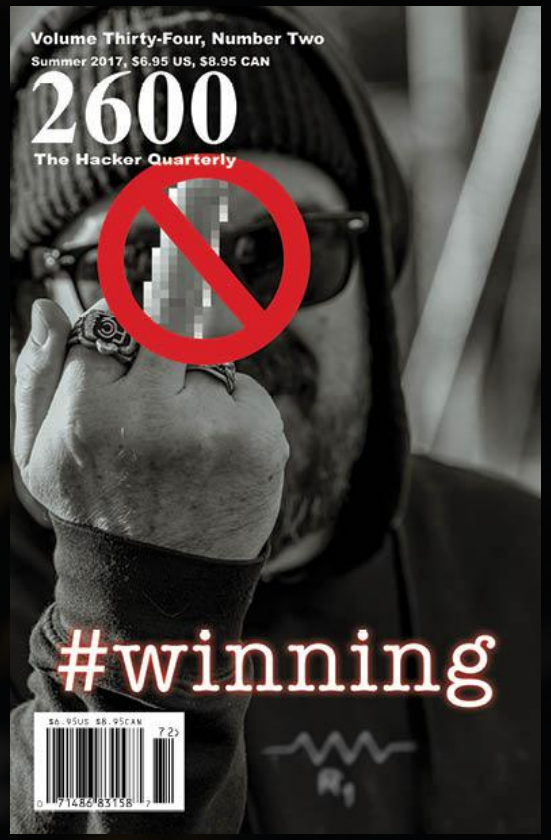
DC25: Community, Discovery and the Unintended Uses of Technology

2600: The Hacker Quarterly



Summer 1992

25 years



Summer 2017

The Evolution of Steganography

DIY Social Steganography

Deep Neural Networks for Social Stego

Data-Driven Red and Blue Teaming

Wrap Up

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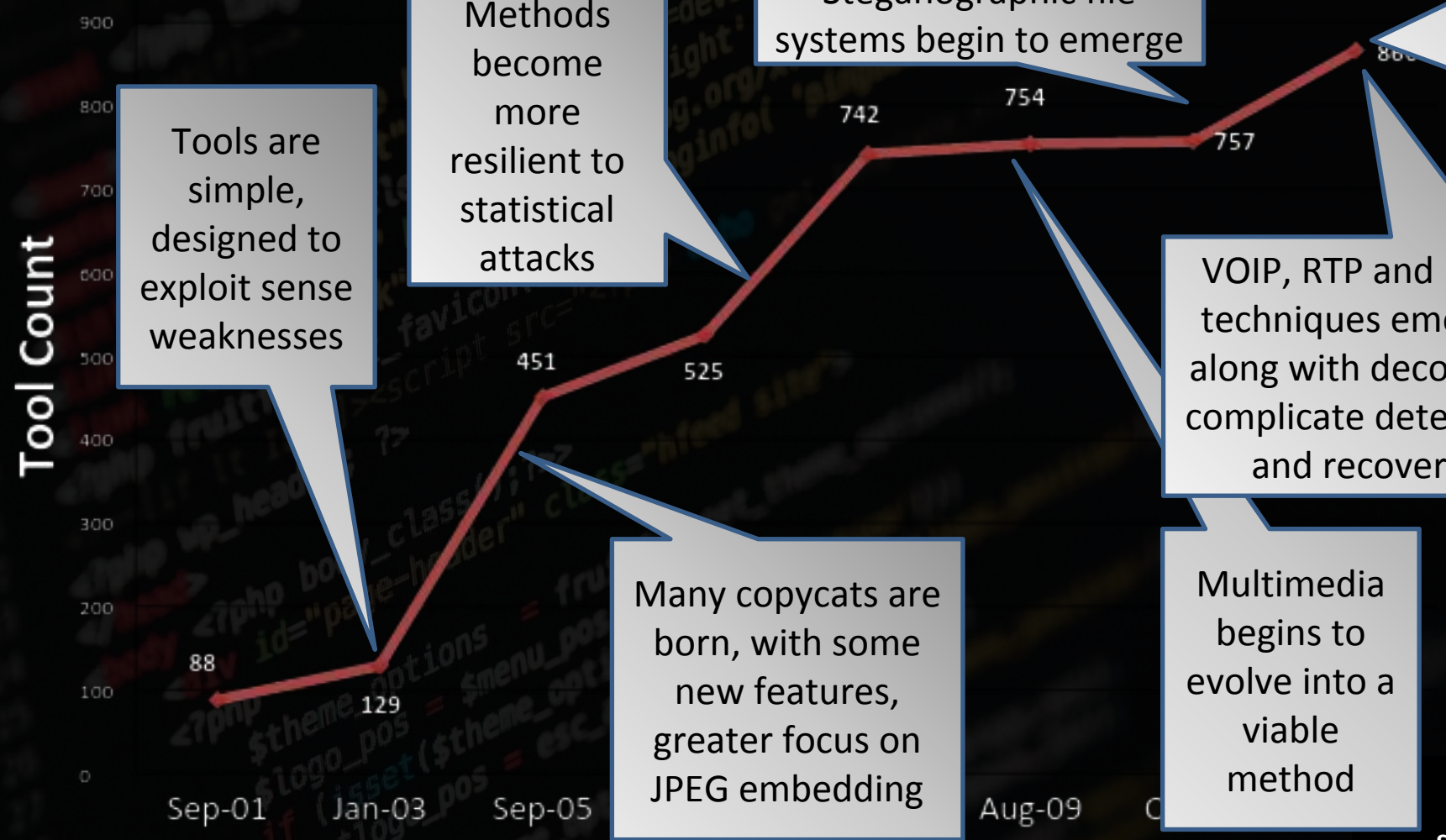
Covert Communication

“. . . any communication channel that can be exploited by a process to transfer information in a manner that violates the system's security policy.”

Source: U.S. Department of Defense. Trusted Computer System Evaluation “The Orange Book”. Publication DoD 5200.28-STD. Washington: GPO 1985

Evolution of Methods



Tools are simple, designed to exploit sense weaknesses

Methods become more resilient to statistical attacks

New versions emerge of existing Alg. Steganographic file systems begin to emerge

Social Media Stego used in images and URLs with malware, CnC, and covert communications

VOIP, RTP and UDP techniques emerge along with decoys to complicate detection and recovery

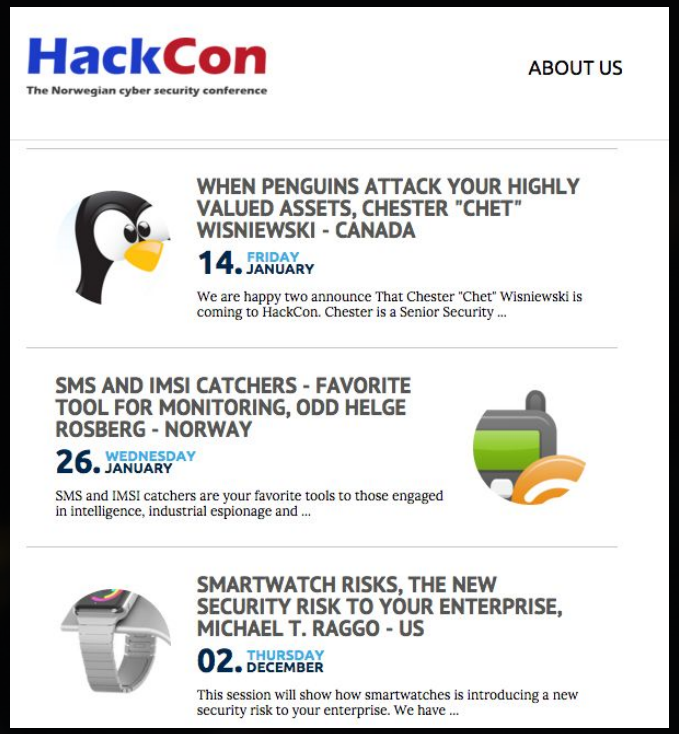
Many copycats are born, with some new features, greater focus on JPEG embedding

Multimedia begins to evolve into a viable method

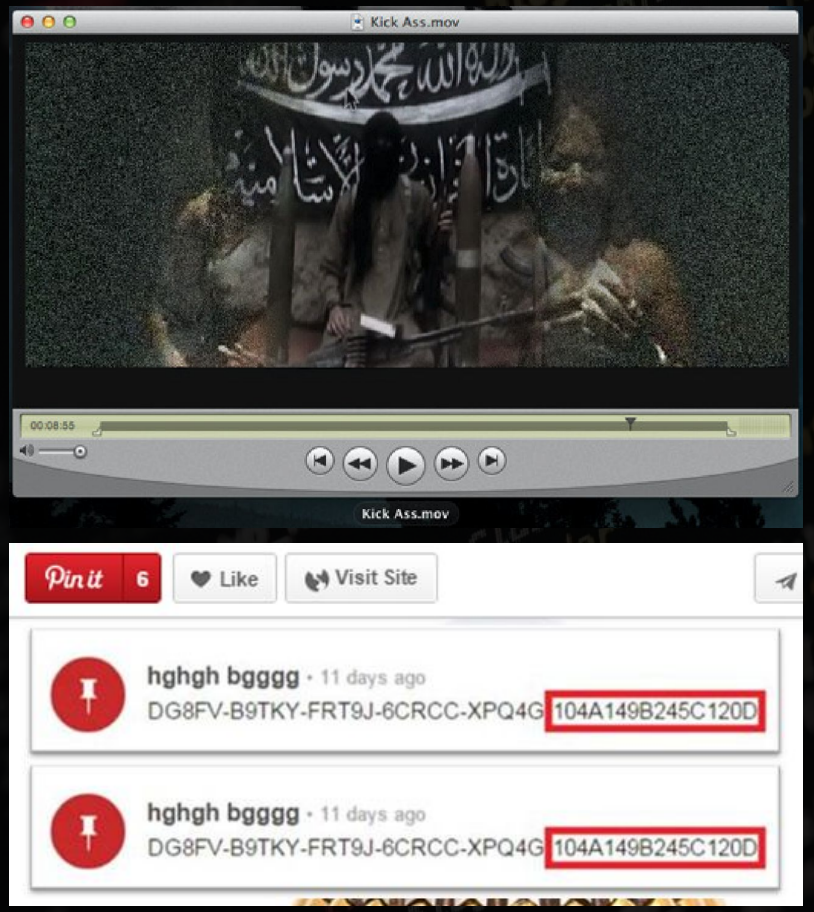
WetStone Labs
Collected Steganography Programs
Since January 1999 Includes versions

Evolution of Stego - Internet Era

- Stego Apps Decoy Techniques (OpenPuff)
- Stealth Alternate Data Streams (NT)
- Weaponized CnC - Operation Shady RAT
- Protocols - VOIP, RTP, UDP => WiFi StegoStuffing, Bluetooth (Hosmer/Raggo - Wall of Sheep/Skytalks DEF CON 23 & 24)
- SmartWatch SWATtackhide.py Tizen SDK - Mike Raggo - DEF CON 23 Demo Labs & HackCon
- MP3 ID3 Metadata exploitation - Hosmer/Raggo Skytalks DC24



Types of Steganography



TrendMicro

- Text/Linguistic Stego - Natural Language
- Image
  - Spatial (e.g. LSB)
  - Frequency (DCT/DWT)
  - Metadata (varies by file type and versions) - JPEG EXIF vs. JFIF
- Audio
- Video
- Protocols
- Use of crypto with stego
  - Vigenere, base64, XOR, etc.

DIY Social Steganography

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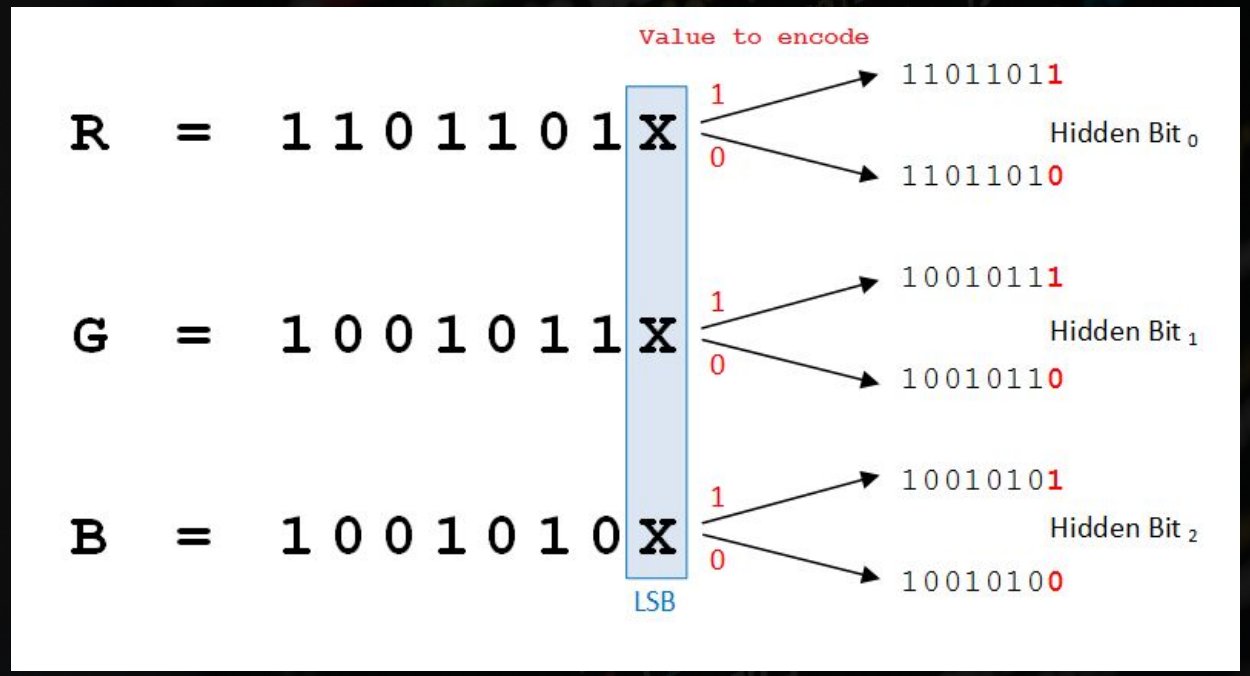
Social Network Photo Targets

- Profile Image
- Background Image
- Posted Image(s)
- Photo albums
- DM images
- Links to images on other websites

Carrier Image File Types

- Image quality properties:
  - Lossy v. Lossless Raster Compression
- Common file formats:
  - JPEG (Lossy)
  - PNG (Lossless)
  - TIFF (Lossless)
  - GIF (Lossless)
  - BMP (Lossless)

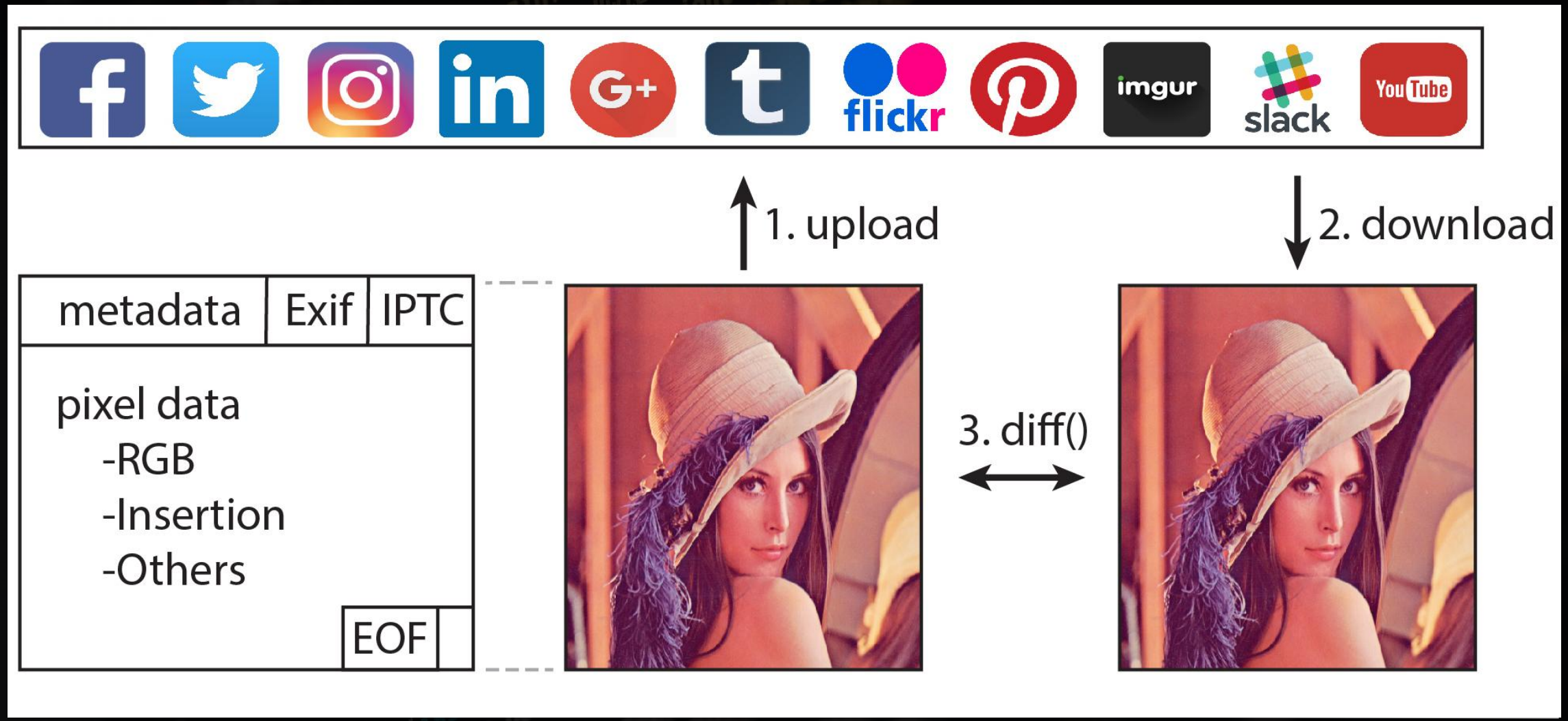
Trial and Error - Attempted Methods



DataGenetics

- Metadata fields (varies by image types JPEG EXIF vs. JFIF, etc.)
- LSB - Least Significant Bit
- Insertion
- Append after EOF marker
- Linguistic Steganography
- Round trip: pre/post upload

High-Level Testing Workflow



Social Network Data Hiding Survivability Testing

Social Network	Profile Photo	Post an Image	Background Image	Album, Book, Board	Round-trip (pre/post upload)	Audio (MP3)
Pinterest	No	Yes		Yes		
Insertion	No	Yes		Yes		
LSB	No	Yes		Yes		
Metadata	No	Yes		Yes		
Instagram	No	No				
Twitter	No	No	No		No	No
Facebook	No	No	No		No	
Slack		Yes				
Insertion		Yes				
LSB		Yes				
Metadata		Yes				
Tumblr	No	No	No	No	No	Yes
Insertion	No	No	No	No	No	Yes
LSB	No	No	No	No	No	Yes
Metadata	No	No	No	No	No	Yes
Google+		Yes			Yes	
Insertion		Yes			Yes	
LSB		Yes			Yes	
Metadata		Yes			Yes	

Deep Neural Networks for Social Stego

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Signals in the Social Noise

4.75 billion
pieces of content shared per day.

100+ hours
of video uploaded per minute.

500+ million
tweets per day.

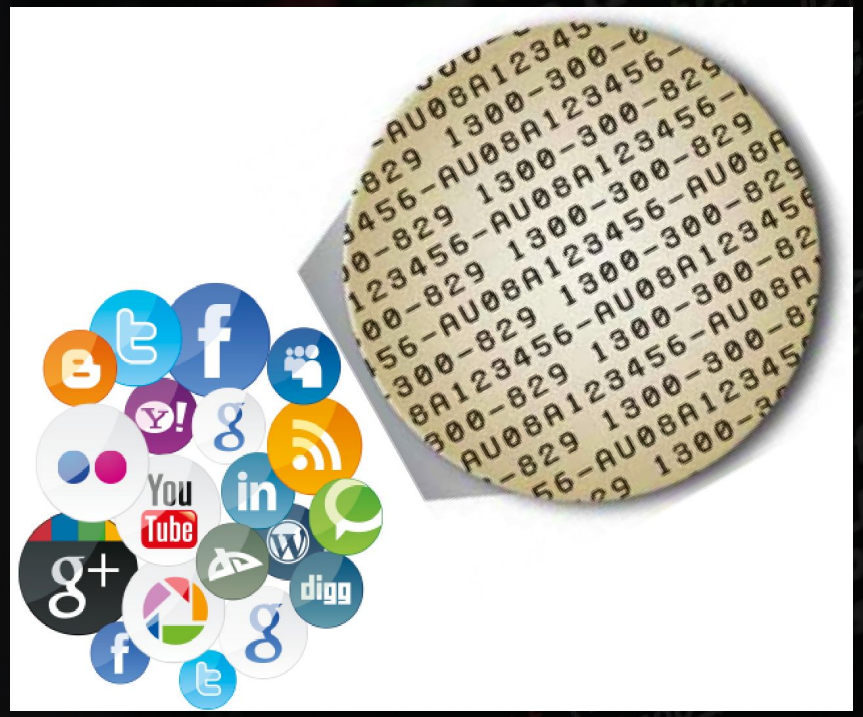
80+ million
images uploaded per day.

5 billion
+1's per day.

Social Network Image Proliferation

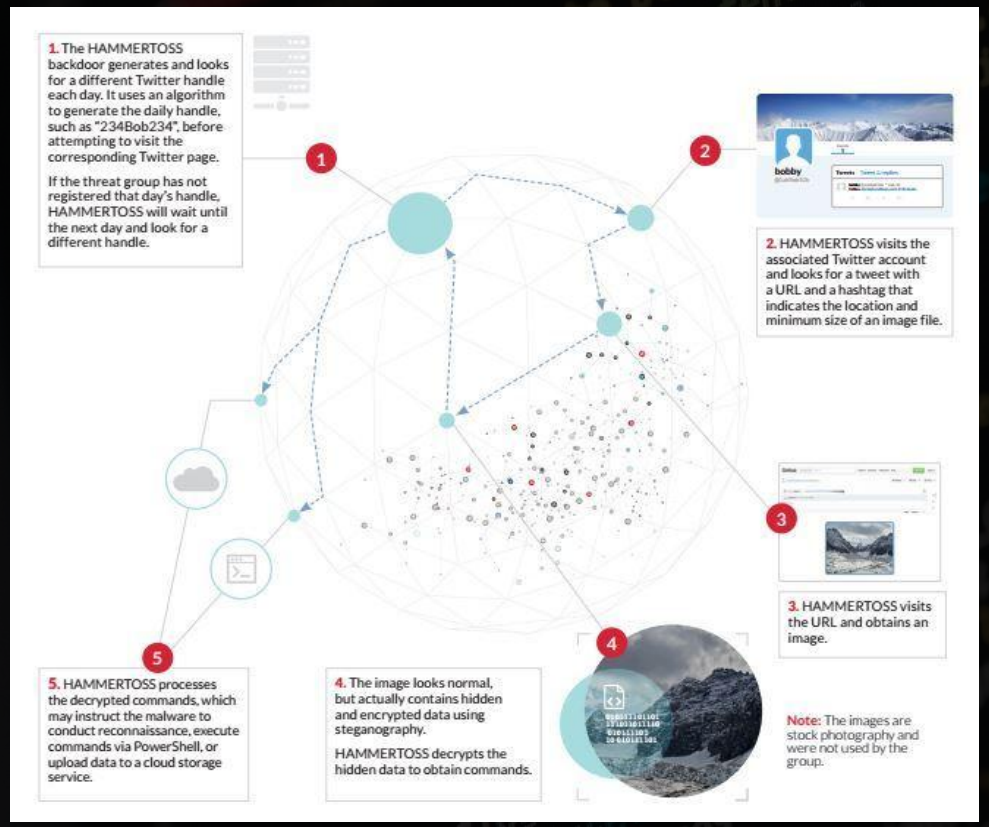
- Image-based social networks have the fastest growing user bases
- Image-based social networks enjoy the highest daily time spent by users
- “Photos or Images” is the content category most frequently shared
- Social posts containing images produce 650% higher engagement than text alone

Social Networks as Stego Conduits

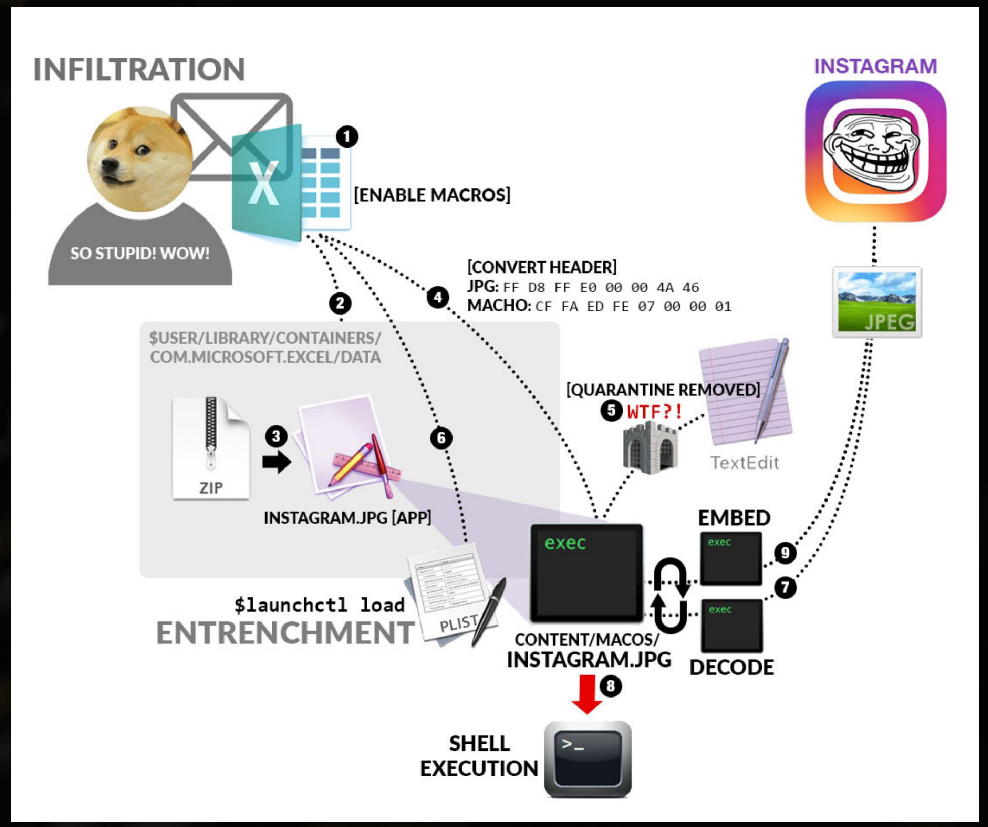


- Heavily trafficked, tons of images
- Public nature and #broadcast capabilities
- Convenient APIs for sharing (uploading / downloading) content for devs & apps
- Fake account creation is trivial
- Lack of IoC's from network perspective
- Wild examples - C&C, malware, phishing

Social Stego in the Wild

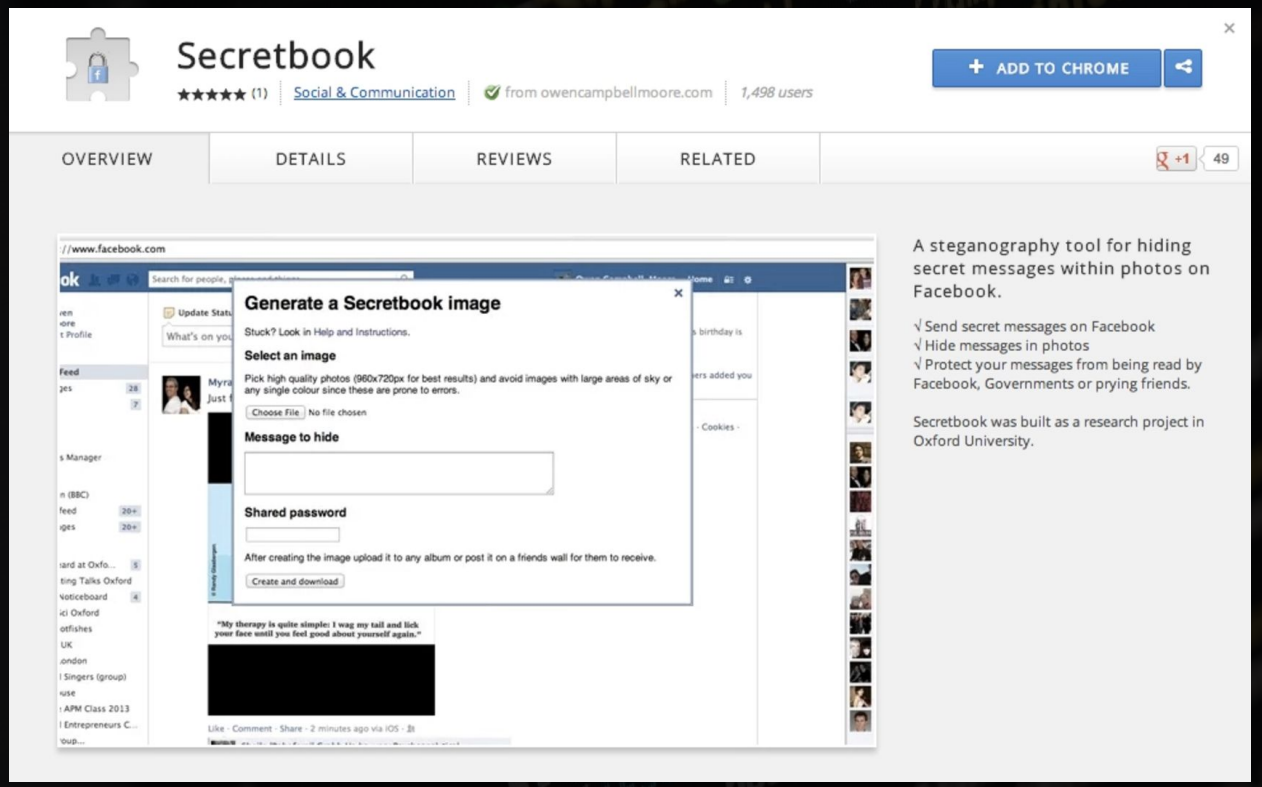


Black Hat: HAMMERTOSS [FireEye]



White Hat: Instegogram [ENDGAME]

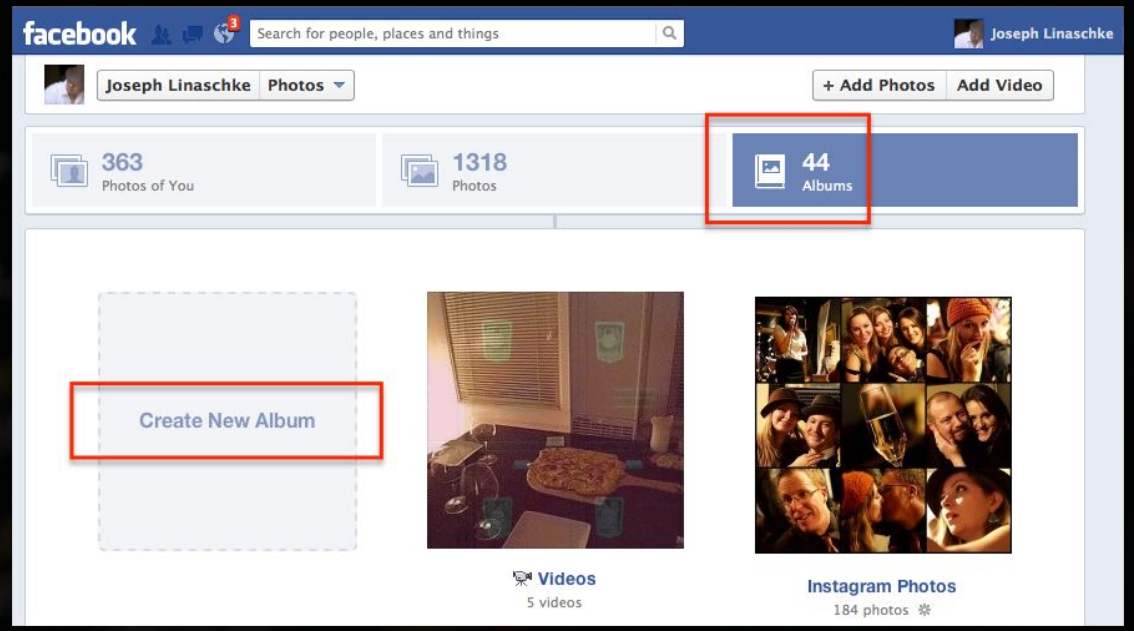
Secretbook by Owen Campbell-Moore



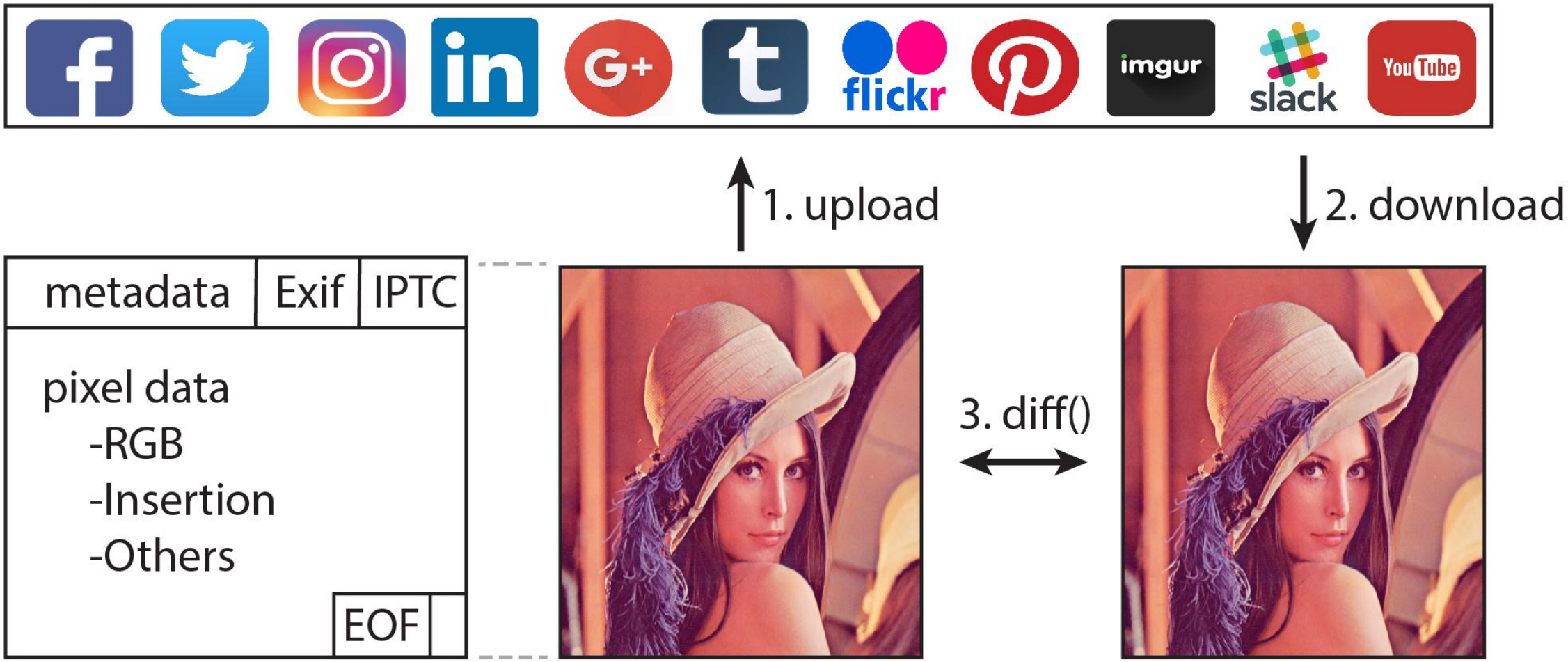
- Open-source Social Stego tool
- Chrome Extension (2013)
- Reverse engineered Facebook's lossy compression algorithm
- Allowed for payloads of up to 140 characters in length
- Other heuristic DCT schemes exist

Bulk Image Uploads/Downloads

- Data Acquisition made easy
  - Permissive APIs for content creation
  - More content=more engagement=profit
- Off-the-shelf photo aggregators
  - Facebook albums
  - Pinterest boards
  - Flickr sets
  - Google+ Collections
- Or we can do it the ‘hard way’
  - for photo in album{
    upload(photo); sleep(randInt); }



Automated High-Level Testing Workflow



Jamming Techniques

How can I make sure that my photos display in the highest possible quality?

Desktop Help Mobile Browser Help Other Help Centers Share Article

We automatically resize and format your photos when you upload them to Facebook. To help make sure your photos appear in the highest possible quality, try these tips:

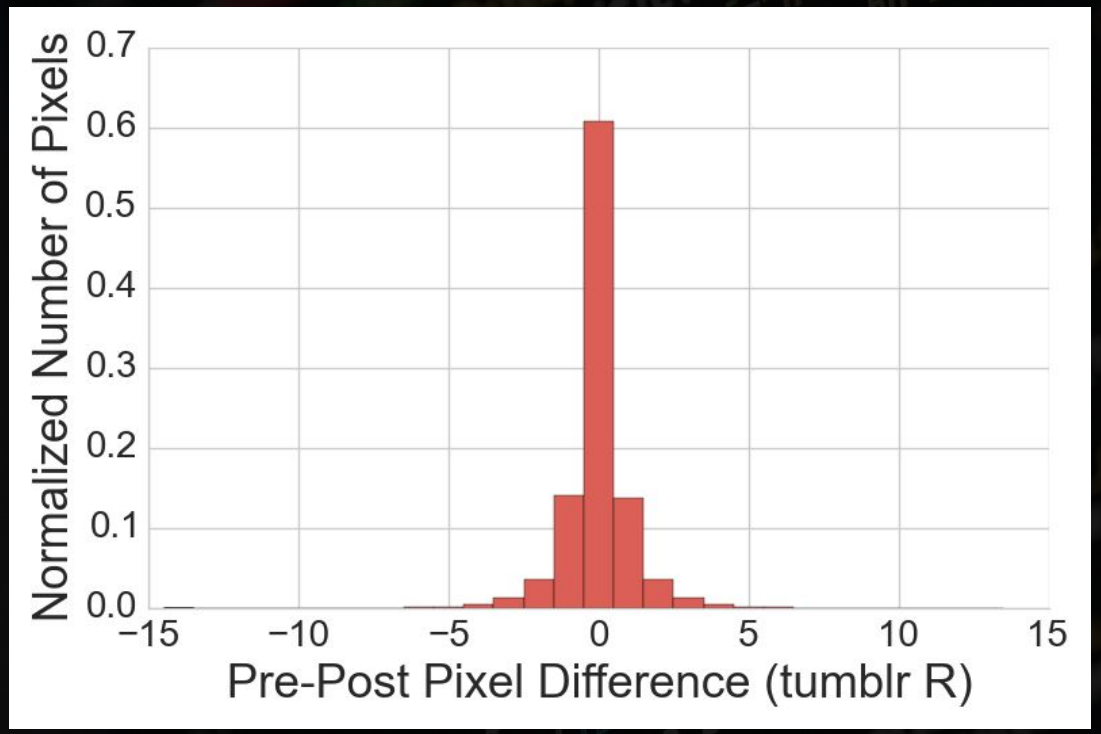
- Resize your photo to one of the following supported sizes:
  - Regular photos: 720px, 960px or 2048px wide
  - Cover photos: 851px by 315px
- To avoid compression when you upload your cover photo, make sure the file size is less than 100KB
- Save your image as a JPEG with an sRGB color profile

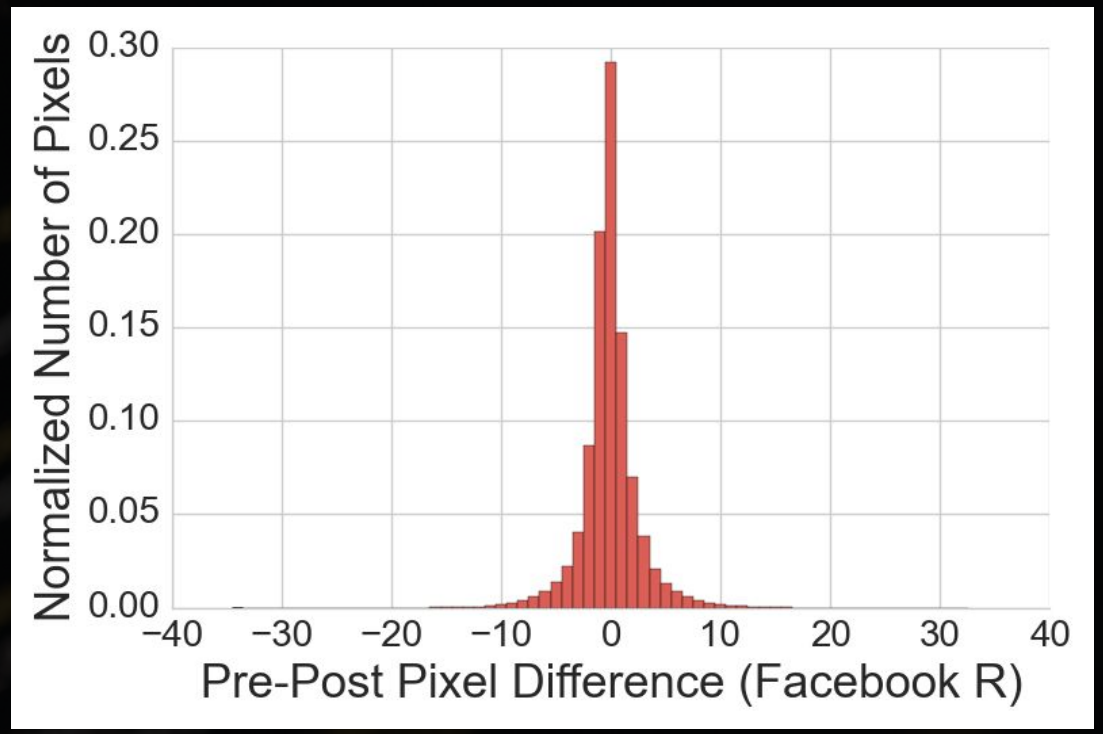
You can also change your settings so that your photos are uploaded in HD by default.

Was this information helpful?
Yes No

- Server-side image upload restrictions and alterations
  - Fast mobile content delivery
- Common Image upload Alterations:
  - Compression
  - Lowpass filtering (slight blur)
  - Metadata stripping
  - Filetype conversion
  - Resizing
  - Alpha compositing

Targeting Unaltered Carrier Pixels





Auto-Generating Data

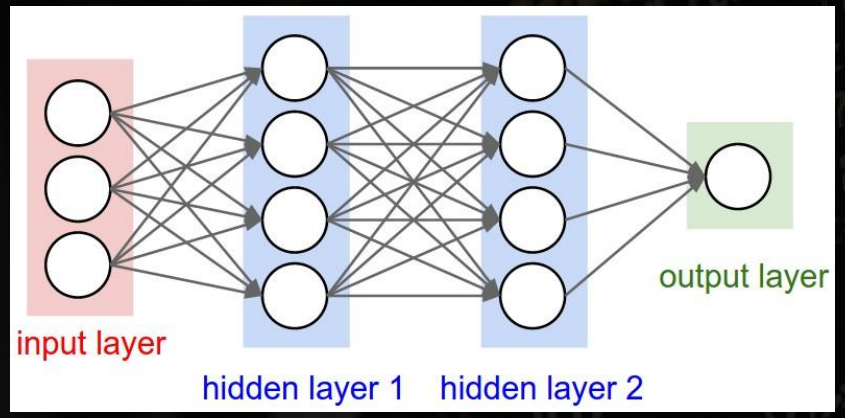
- Select ~50k samples (e.g. ImageNet)
- Automate uploads and downloads
- =100k pre-uploaded and downloaded images
- Compare pixels between phases
- Can location choices be automated?
- ‘Classic’ Neural Nets don’t scale to images
  - width * height * 3 channels = unmanageable # weights
  - encode these properties into the architecture

What humans see

08 02 22 97 38 15 00 75 04 05 07 78 52
49 49 99 40 17 81 18 57 60 87 17 40 98
81 49 31 73 55 79 14 29 93 71 40 67 53
52 70 95 23 04 60 11 42 69 24 65 56 54
22 31 16 71 51 67 63 89 41 92 36 54 22
24 47 32 60 99 03 45 02 44 75 33 53 78
32 98 01 20 64 23 67 10 26 38 40 67 59
67 26 20 68 02 62 12 20 95 63 94 39 63

What computers see

Convolutional Neural Networks



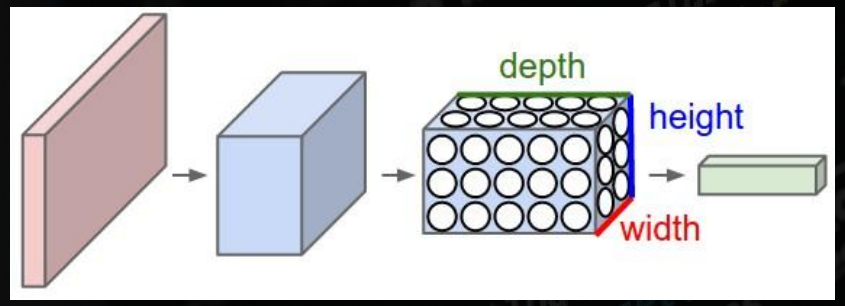
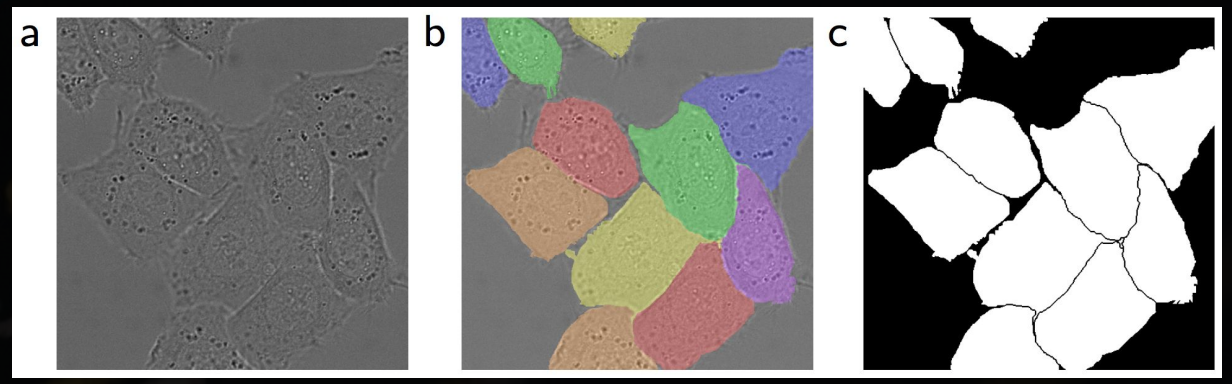


Illustration: Andrej Karpathy
CNNs: Szegedy, Toshev & Erhan, 2013

- Proven great for Computer Vision Tasks
  - Object classification, Facial recognition
- Pose as Binary Classification Tasks
  - Locate optimally embeddable pixels
  - Akin to image segmentation
  - Feedforward networks and function approximation
- Model spec
  - Keras on top of TensorFlow (Python)
  - Google GPU (8 vCPU Nvidia Tesla)
  - contracting/expanding, ~23 layers fed thru ReLUs

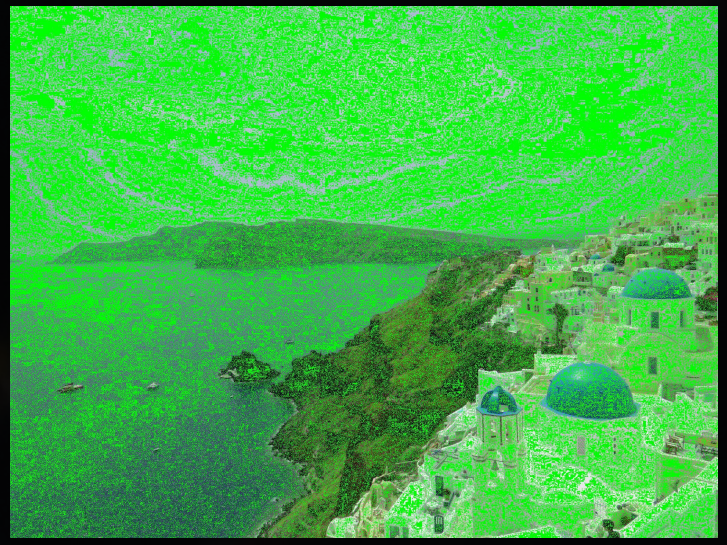
Image Segmentation - Predict Binary Masks



Left: DeepMask [Facebook Research]
Above: u-net [Ronneberger *et al*]

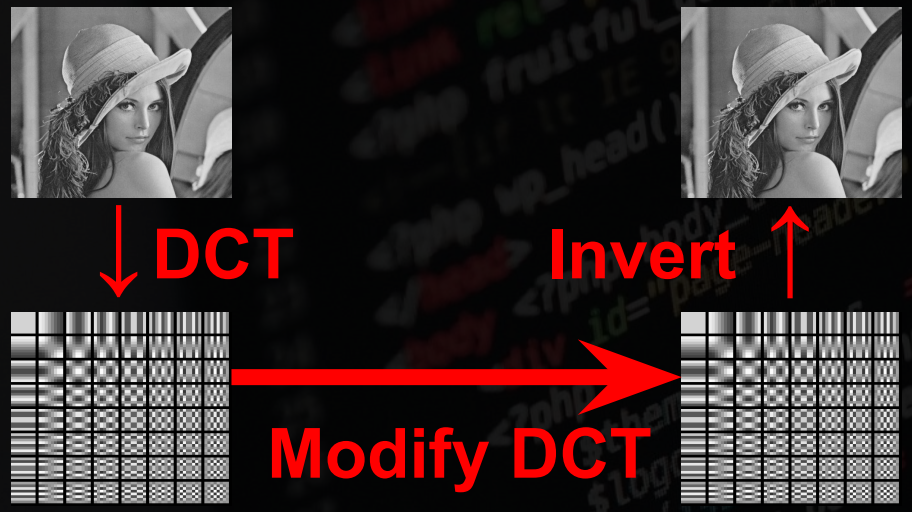
Prototype Evaluation

- More robust, less detectable transmission
- Recovery rates worsen with len(hidden data)
  - 94.1% accuracy (FPs=lost data, FNs=lower capacity)
- Minimizes Visual Dissimilarity
  - Distortion: peak signal-to-noise ratio, MS-SSIM
  - Capacity: bit survivability
  - Otherwise, watermarking
- Learned pixels correlate w/ carrier locations that are more complex and “busier”



Innovation and Novelty

Spatial Steganography



Frequency Steganography

- Spatial stego = more storage capacity than frequency stego, compression-intolerant
- Previous ad hoc approaches weren't data-driven. Learn from uploads (feedback)
  - Updated processing logic = retrain
  - In principle, generalizes across social networks
- No need to know implementation details of compression or other nonlinear processing
  - Documentation not usually available anyway

Data-Driven Red and Blue Teaming

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InfoSec ML Historically Prioritizes Defense

WILLIAM YERAZUNIS

Keeping the Good Stuff In: Confidential Information Firewalling with the CRM114 Spam Filter & Text Classifier

CLONEWISE - AUTOMATED PACKAGE CLONE DETECTION

Presented By:
Silvio Cesare

DEFENDING NETWORKS WITH INCOMPLETE INFORMATION: A MACHINE LEARNING APPROACH

PRESENTED BY
Alexandre Pinto

A SCALABLE, ENSEMBLE APPROACH FOR BUILDING AND VISUALIZING DEEP CODE-SHARING NETWORKS OVER MILLIONS OF MALICIOUS BINARIES

PRESENTED BY
Joshua Saxe

FROM FALSE POSITIVES TO ACTIONABLE ANALYSIS: BEHAVIORAL INTRUSION DETECTION MACHINE LEARNING AND THE SOC

PRESENTED BY
Joseph Zadeh

TIME

AN AI APPROACH TO MALWARE SIMILARITY ANALYSIS: MAPPING THE MALWARE GENOME WITH A DEEP NEURAL NETWORK

Konstantin Berlin | Senior Research Engineer, Invincea Labs, LLC

Data-Driven Social Engineering

- DEF CON 24
- Why Twitter?
  - Bot-friendly API
  - Colloquial syntax
  - Shortened URLs
  - Abundant personal data
- Machine grammar suffices

Red Team ML Rising

- Growing number of examples:
  - Micro-targeted social engineering
  - Password cracking
  - Captcha subversion
  - AV evasion
  - Steganography
- Offensive ML easier than defensive ML!
  - “Labeling Bottleneck” - unsupervised
- Success matters more for blue than red team
- Retreating barriers to entry
  - More open-source initiatives
  - Cheapening access to powerful machines (eg. GPUs)

Not to worry, though...

- Offensive ML a positive development
- It will “keep us honest”
- Emerging defenses keep pace:
  - Semi-supervised learning
  - Adversarial learning
  - Transfer learning
  - Self-supervised reinforcement learning
- Ultimately fortify security
- Faster this is realized, the better

Wrap Up

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Use Cases


theguardian

US politics world opinion sports soccer tech arts lifestyle fashion business travel environment all

home › US

John McAfee

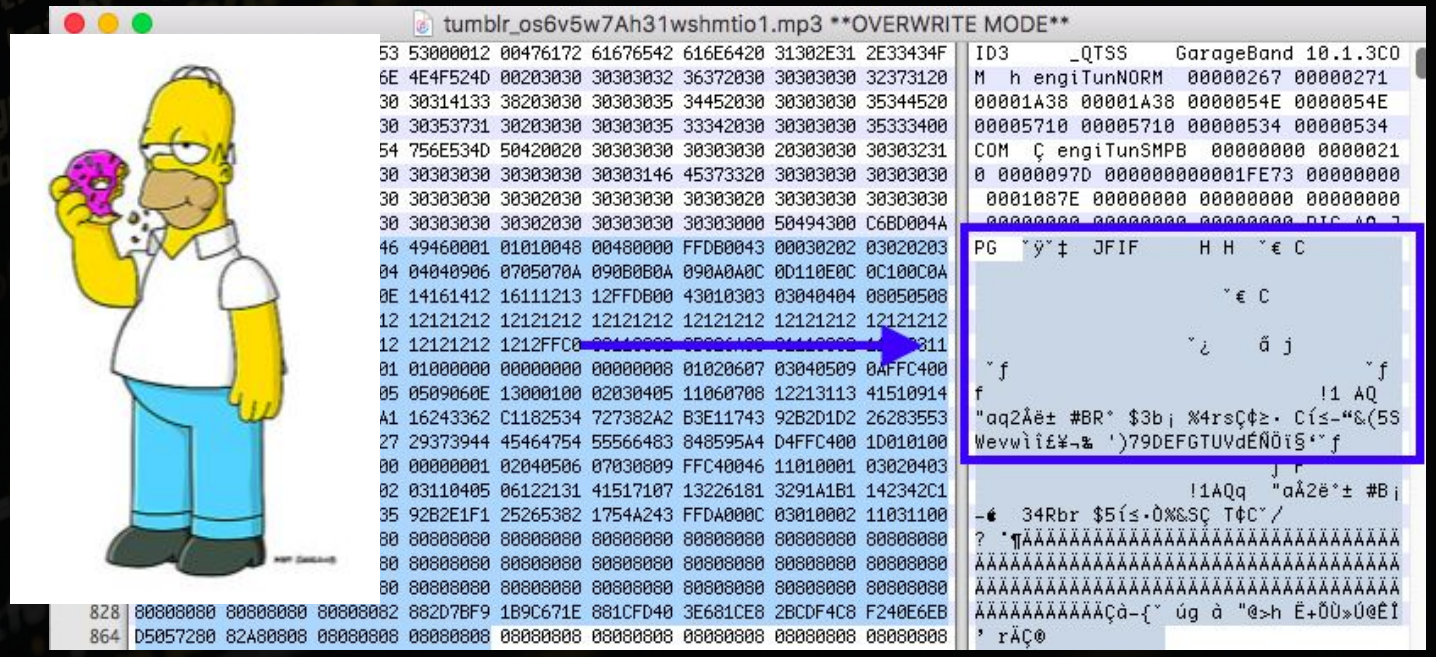
John McAfee's secret location may have been revealed by Vice journalist

Granted access to the fugitive millionaire, magazine apparently neglects to remove location data from photograph's metadata

- Data exfiltration, digital dead drops, C&C
- Bypass online censors
- Privacy - Metadata tracks thru social media. Strip it if there's concern
- Piracy - copyright in metadata
- Social media security awareness

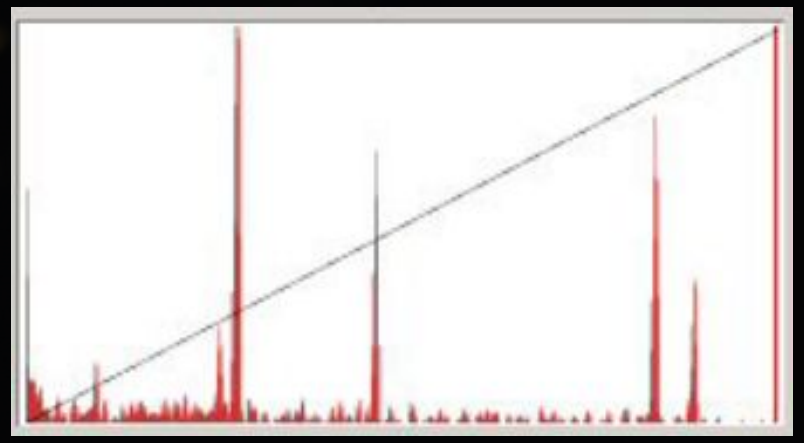
Next Steps

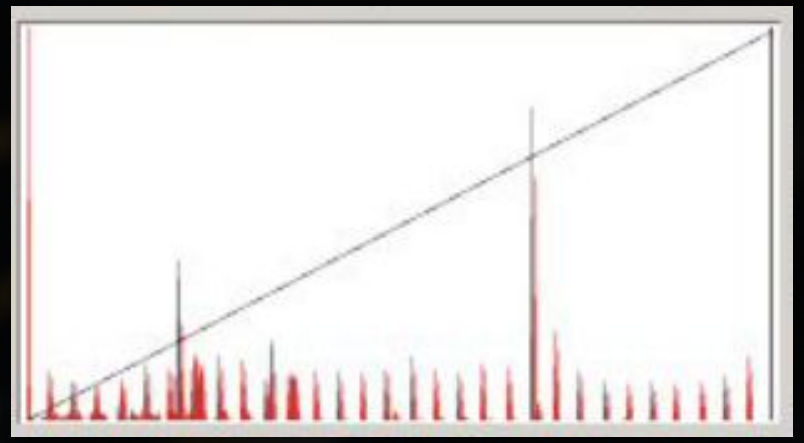
- More social networks, crypto
- Deal w/ filters, resizing
- Fragment/Disperse payload
- Test more file types
  - Video files (MP4, MOV, etc.)
    - News Feed promoted, soon-to-be most popular
  - Audio files (MP3)
    - Create custom MP3s w/ GarageBand, embedded JPEG insertion
    - ID3 Headers DC 24 SkyTalks Hosmer/Raggo www.python-forensics.org



Mitigations

- More dynamic jamming techniques
- Histogram “zigzag” - color quantization
  - Statistical: Means, variances, chi-square tests, linear analysis, wavelet statistics, kurtosis
- Impermanence: delete by default
  - Ephemeral images a la Snapchat
- Steganalysis is hard w/o access to orig image
  - Further obscurement through social’s scale, variance





Summary and Questions

Philip Tully Mike Raggo

@phtully @datahiding

- Social networks and image hosting services can be orthogonally used to transmit data covertly
- Steganography can be automated despite distorting image upload side effects
- Offensive AI is cheaper and easier to implement than defensive AI
- Code to be released on GitHub piecemeal, followed by technical report (WIP)