



Center for Security
Technologies

Document Security

Ronald S. Indeck, PhD

The Das Family Distinguished Professor

Director, Center for Security Technologies

 Washington University in St. Louis

Center for Security
Technologies

Securing our World through Technology

Document Security

- The Center for Security Technologies
 - security and privacy
- Physical documents
 - overview
- Electronic documents
 - steganography

Washington University and the Center for Security Technologies

Securing our World through Technology

- Washington University
 - *USNWR*: ranked 9th nationally, top 10 in endowment
 - 8 Schools: Medicine, Social Work ranked 2nd
- CST
 - interdisciplinary academic research center
(50 faculty from 5 schools)
 - built on existing strengths
in security research



Security While Remaining Free and Open

- Technology expected to (and will!) respond with improved solutions to threats new and existing
 - applies to both planned and natural attacks
- Insist on coordination with law, privacy, economics, and public policy
 - expect reason to be applied

Reasons for Document Security

- Authentication/verification
- Copy protection
- Detection of data integrity/manipulation
- Traitor tracing
- Forensics
- . . .

Physical Documents

- Includes paper, containers, objects, . . .
- Produce authentic documents/articles
- Authenticate genuine document
- Verify data of object
- Determine if copied and where copies came from
- . . .

Electronic Documents

- Includes text, audio, video
- Transmission as well as storage
- Determine authenticity
- Verify if altered
- Protect intellectual property
- Trace copies
- . . .

Some Considerations

- Cost – including infrastructure and societal
- Ease of manufacture/creation
- Ease of duplication
- Ease of measurement
- Overt/covert
- Protection or authentication
- How often will it need to be examined?
- Who has the right to secure or verify or clean?
- Legal (do you need to have original in court)

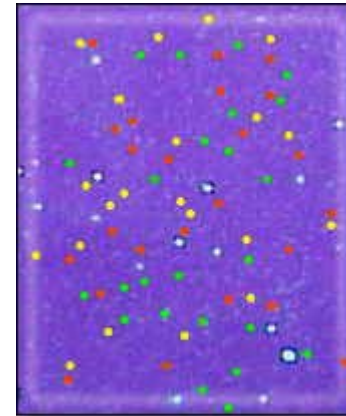
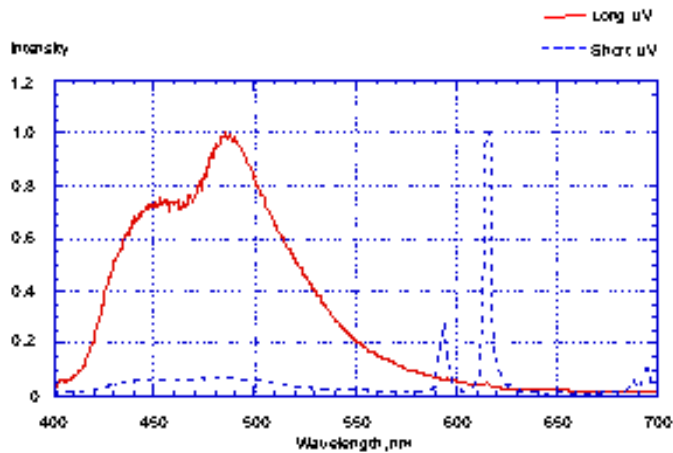
Physical Solutions

- Printing
 - inks, wavelengths, magnetic particles, physical particles, DNA-typing, dye migration, age
 - secure paper
 - process: shifting, micro-printing
- Additional materials
 - holograms
 - random particles and taggants
 - labels
- One time use 2D bar code
- Chips inside
-

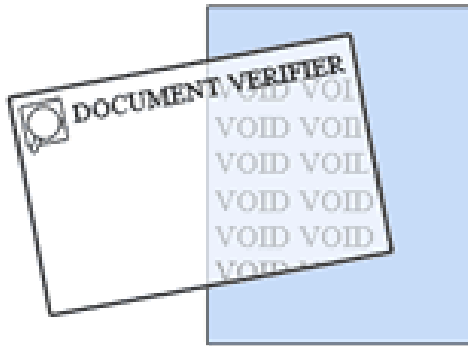
Multi-wavelength Fluorescence



Spectra Systems
CORPORATION



Secure Papers



Verify First Technologies



Magnetic Fingerprinting

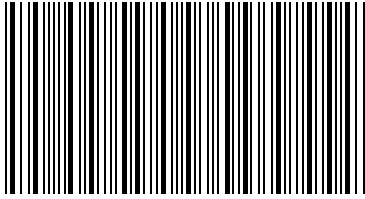
- A medium's *physical microstructure*
 - non-removable
 - recoverable
 - irreproducible, unique feature
- This distribution can be quantified and used as a “fingerprint” of the object



MAGTEK®

Solutions to Electronic Fraud

- Digital fingerprinting and watermarking
- Authentication
- Traitor tracing
- Storage at a TTP
- PKI
- Hashing/date & time stamping
- . . .



314-935-4767

A bit about Bytes

101110011010101011110010

- 1's and 0's: a trim alphabet
- bits and Bytes: usually 8 bits/Byte
- kilo, Mega, Giga, Tera, Peta, Exa: 10^3
 - kilobyte: printed page of text
 - Megabyte: novel
 - Gigabyte: movie
 - Terabyte: US Library of Congress
 - Petabyte: all US academic research libraries
 - Exabyte: every word produced by humans

Massive Data



- Storage industry will ship 6,000,000,000,000,000,000 Bytes this year;
 - Cost decreasing ~3%/week;
- MasterCard recently installed 200 TBytes of disk storage;
- 120 TBytes/sec Internet peak rate
 - 120 PBytes/month Internet
- Humanoids have produced 12 Exabytes over the past ~30,000 years
 - Next 12 Exabytes in just over a year!

Modern Steganography

- National security/government applications
- More than security: \$
- Multimedia and consumer applications
- . . .



National Security Applications

- Document authentication
 - official documents
 - international communications
- Digital fingerprinting
 - traitor tracing
- Covert communications
 - February 2001: USA Today reported that Osama Bin Laden used steganography to communicate with operative



What is Steganography?

Hiding a secret message inside of an open message

- Steganography = *Covered Writing*
 - Greek word *steganos* means “covered”
 - Greek word *graphia* means “writing”
- the existence of the secret message is not known except to those who are expecting it
- extracting the secret message may require special tools

Steganography Example

A German spy sent this message during WWII:

Apparently neutral's protest is thoroughly discounted and ignored. Isman hard hit. Blockade issue affects pretext for embargo on by-products, ejecting suets and vegetable oils.

Pershing sails from NY June 1

Other Examples in History

Herodotus tells of a slave sent by his master, Histiaeus, to the Ionian city of Miletus with a secret message tattooed on his scalp in 440 BCE. After tattooing, the slave grew his hair back in order to conceal the message. He then journeyed to Miletus and, upon arriving, shaved his head to reveal the message to the city's regent, Aristagoras. The message encouraged Aristagoras to start a revolt against the Persian king.

During the American Revolution, invisible ink which would glow over a flame was used by both the British and Americans to communicate secretly.

In World War I, prisoners of war would hide Morse code messages in letters home by using the dots and dashes on i, j, t and f.

During World War II, the Germans would hide data as microdots. This involved photographing the message to be hidden and reducing the size so that that it could be used as a period within another document.

Steganography and Watermarks

Steganography: The message hidden is a secret and it is *not* generally related to what it's hidden in

Watermarking: The message embedded might not be a secret (it might not even be hidden!) and *does* relate to what it's in



What Does Digital Mean?

Representing signals (such as words, sounds, and pictures, for example) with numbers

- A CD stores about 74 minutes of music with about 400 million numbers
- A typical digital picture requires around a million numbers to represent

Code Table to Digitize Words

a	1
b	2
c	3
d	4
e	5
f	6
g	7
h	8
i	9
j	10
k	11
l	12
m	13

n	14
o	15
p	16
q	17
r	18
s	19
t	20
u	21
v	22
w	23
x	24
y	25
z	26
space	27

Digital Text

“meet me behind the restaurant at midnight”

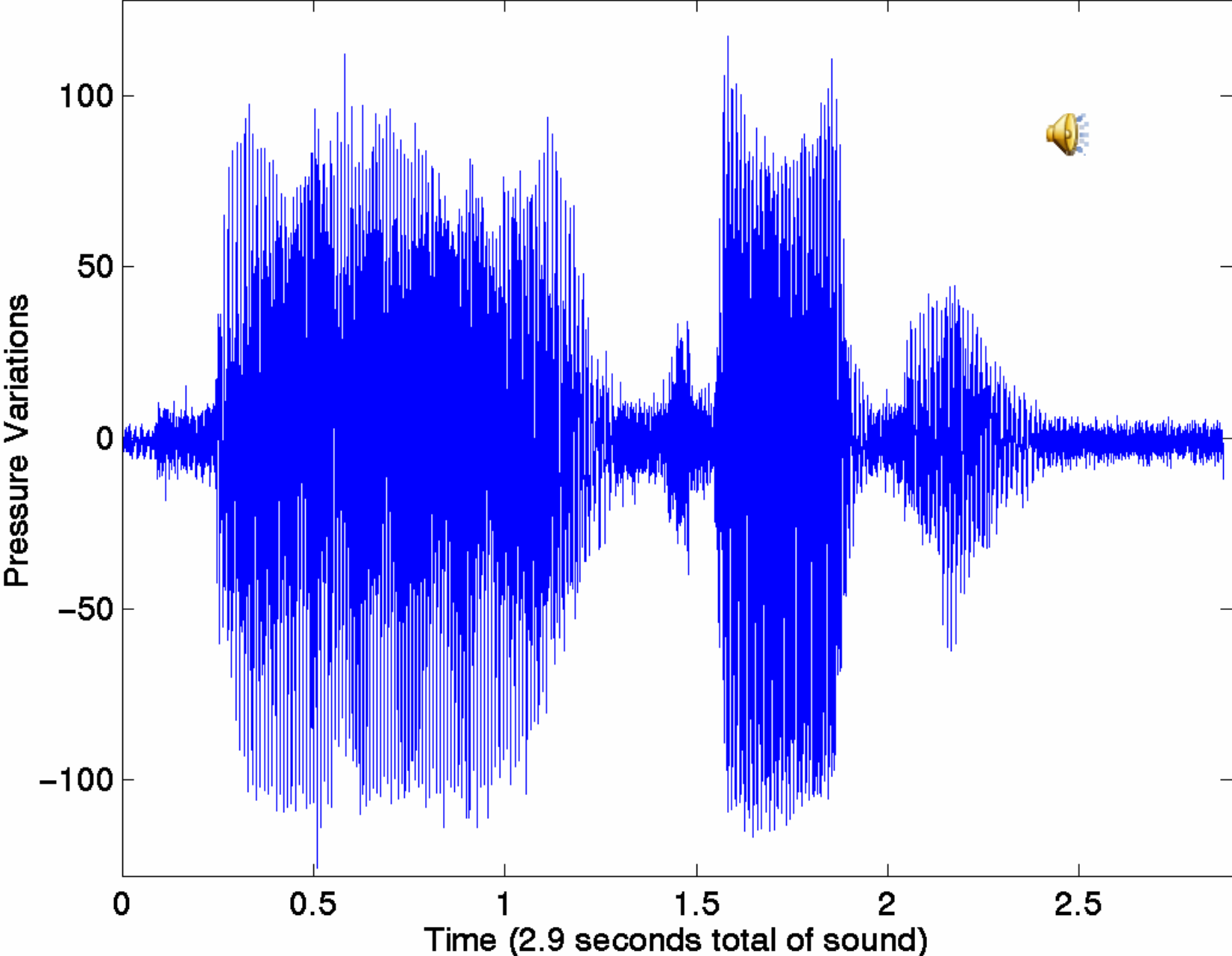


ENCODER

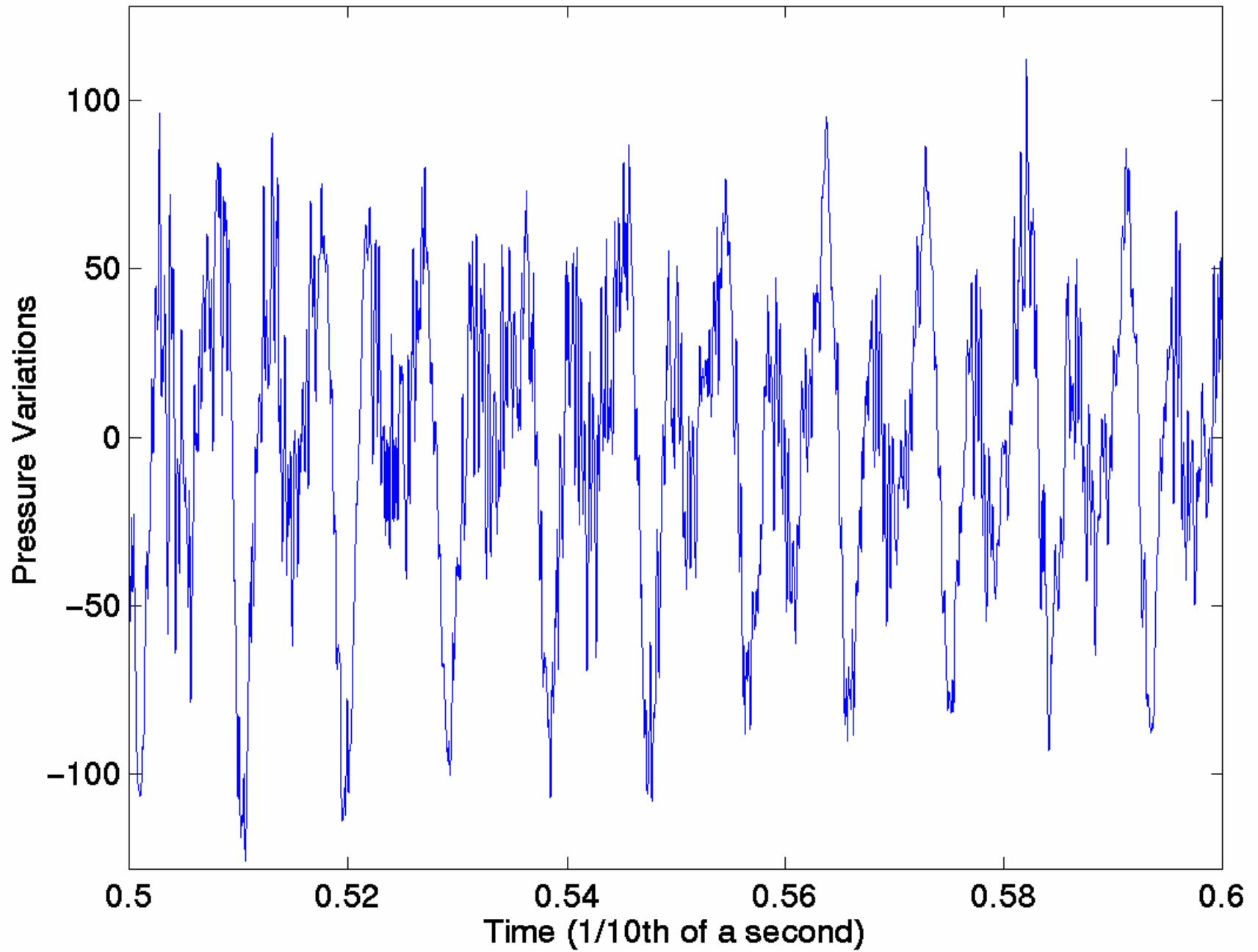


13 5 5 20 27 13 5 27 2 5 8 9 14 4 27 20 8 5
27 18 5 19 20 1 21 18 1 14 20 27 1 20 27
13 9 4 14 9 7 8 20

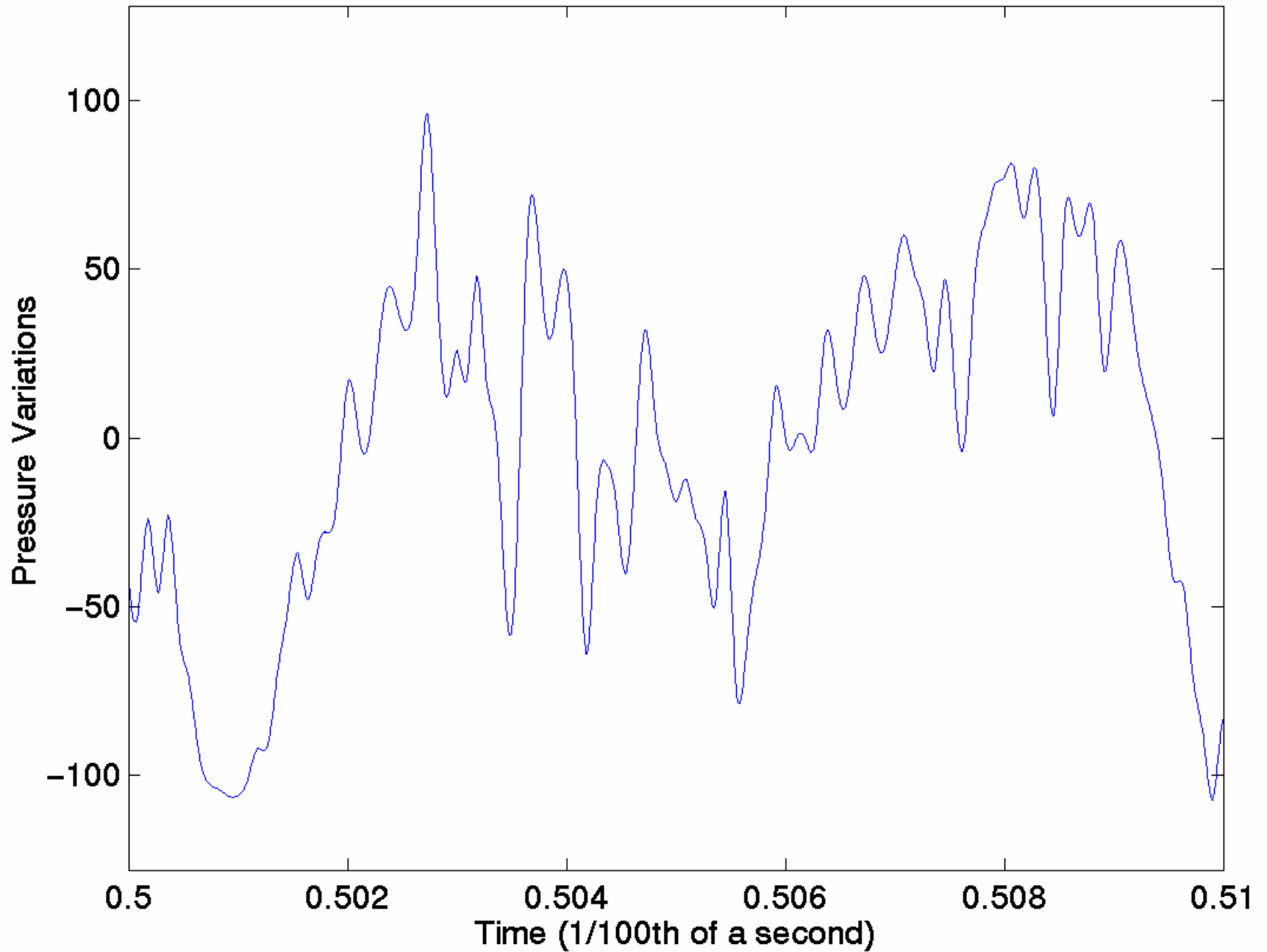
Sound Signal



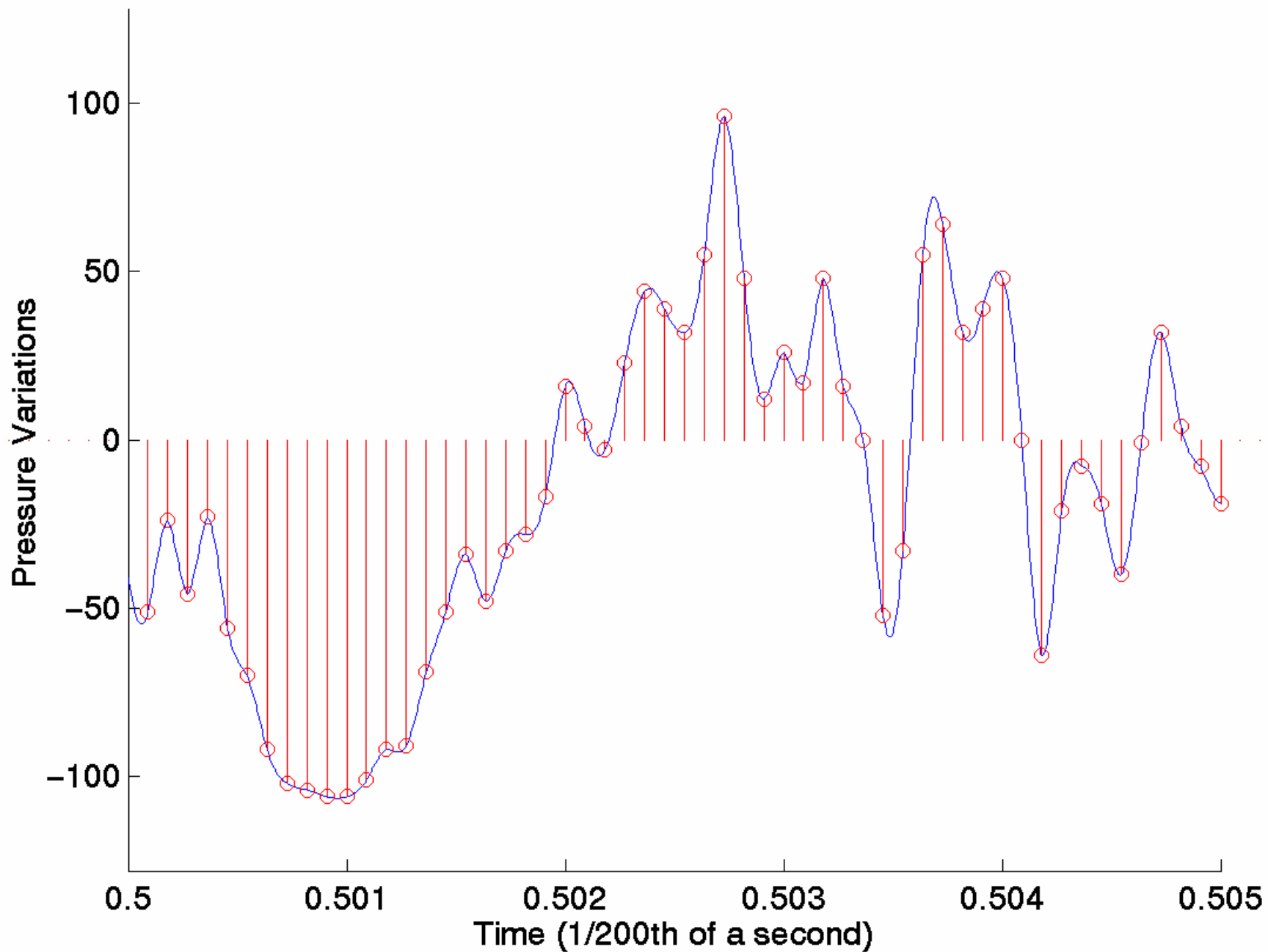
Sound Signal



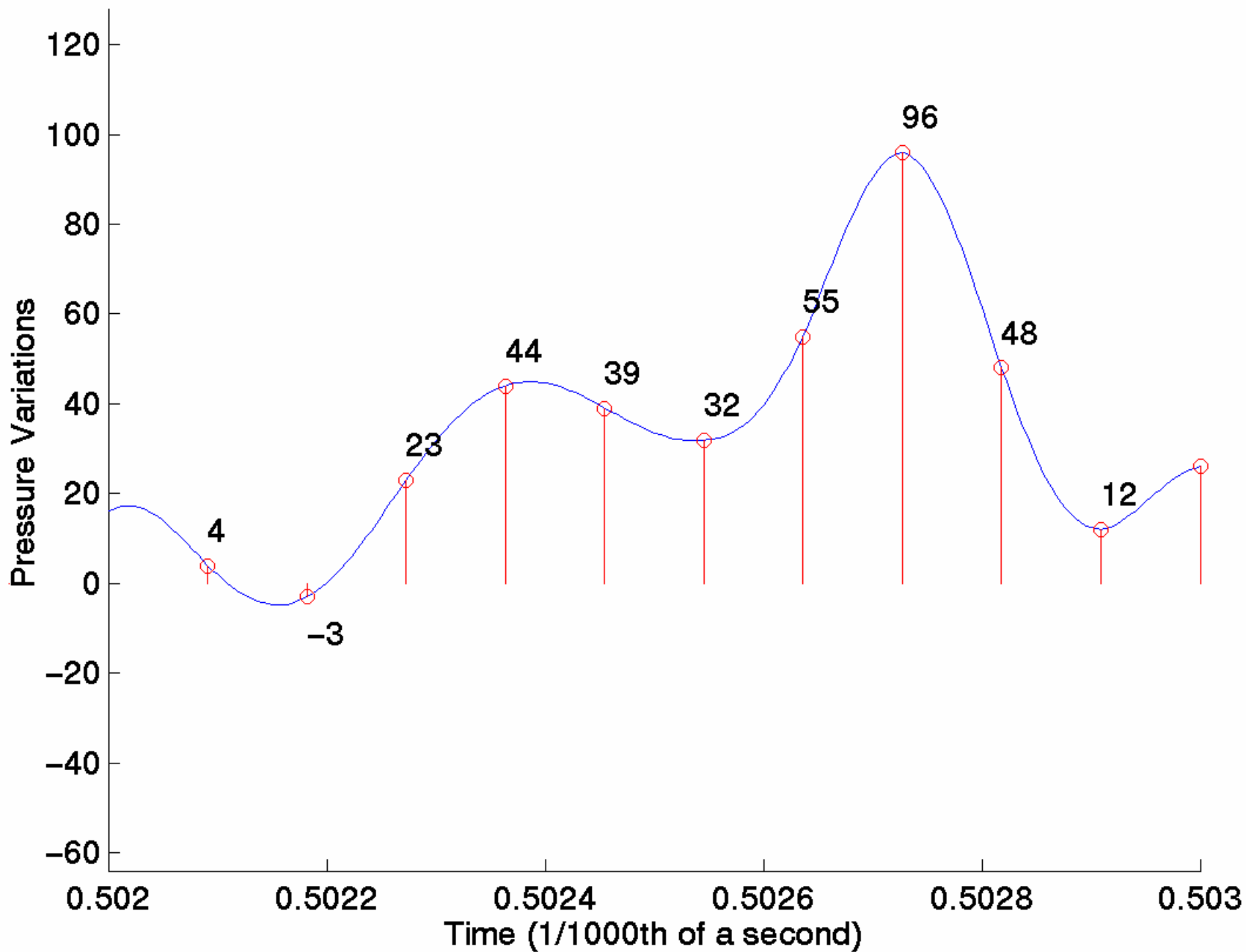
Sound Signal



Sound Signal and Samples



Sound Signal



0 -3 -1 0 0 2 -4 -4 -2 0 1 -2 0 -3 1 -1 0 -3 -1 1 0 -3 -1 1 -1 2 0 -3 3 2 4 4 7 -1 -5 -4 3 -2 -2 1
-2 -1 0 1 -1 0 -3 -4 -3 -2 2 -2 -2 -2 3 -1 -1 -1 0 0 -3 -3 0 -1 0 -3 -3 -2 4 1 0 -4 2 -1 -6 -5 0 -2 -2 0
-3 -1 -1 0 0 0 -4 -3 -2 -1 2 -4 -2 -1 2 0 -1 -2 -1 -1 -2 -4 0 1 3 -2 -2 0 5 -1 -4 -3 0 -1 -5 -7 3 -1 -3 -3
-2 -1 -1 0 -2 1 -4 -3 -2 -1 0 -3 -4 -1 2 -2 -3 -1 0 0 -2 -4 -1 0 1 -5 -3 -3 4 5 -5 -7 -1 2 -7 -6 6 1 -6 -1
-3 -1 0 -2 -3 0 -2 -4 -3 1 1 -4 -1 -1 -2 -2 -1 -1 4 -5 -1 0 -2 -1 -5 -4 4 -3 1 5 -12 -3 4 -4 -6 6
-2 -2 2 -1 -2 0 -4 -2 -4 0 2 -4 -1 -2 0 -1 -2 -1 1 0 -3 -1 -1 -4 -3 -6 0 -3 2 2 5 -7 -4 3 -6 -3 2
-2 -1 0 0 -2 0 -5 -4 -2 1 0 -5 -2 -1 -1 0 2 -1 -6 -1 1 -5 1 3 -1 -7 -4 -2 3 2 -8 -4 1 -7 -2 2
-3 -1 -1 -4 -4 1 -3 -4 -0 0 -3 -2 2 -1 -3 -2 -1 2 3 -2 0 1 2 2 3 -4 -4 -1 -1 2 -11 -4 -2 -5 -1 1
-3 -2 -1 -1 -1 2 -4 -6 -1 1 2 -4 -3 -2 3 -4 -3 -2 -1 0 -5 -2 0 0 0 -1 3 3 1 -1 -5 -6 5 1 -6 -3 -3 -1 -2 -1
-4 -3 -1 -2 -1 3 -3 -4 -1 0 3 -3 -4 -1 2 -1 -2 -3 -1 -2 -3 -6 -1 -1 1 3 10 4 2 0 -3 -14 5 0 -3 -8 -3 3 2 -2
-3 -3 0 -1 -3 3 -4 -4 -2 0 3 -3 -4 -1 2 -2 -1 -1 1 -2 -4 -2 -1 0 0 2 8 0 1 1 2 -18 0 3 -3 -9 -2 4 1 -1
-5 -2 0 1 -2 4 -4 -4 -2 -1 0 0 3 0 1 -1 2 0 1 -3 0 1 0 -1 -2 4 -4 0 2 4 -11 -1 0 -2 -8 -5 2 -1 1
-5 -2 0 1 -4 2 -1 3 -3 -1 1 -2 -0 1 -2 -2 1 1 -6 -3 -1 -2 0 -1 2 -1 0 0 -7 -2 -1 -3 -9 -1 -2 -4 2
-3 -1 -1 0 -2 1 -2 -4 -3 -1 -1 -4 -1 2 -5 -1 -1 0 -3 -2 -1 -2 -6 1 -4 -1 1 2 -8 -8 -6 -4 3 -1 -6 3
-3 -4 -1 0 -1 0 -2 -2 -2 2 2 -3 -0 0 -4 -2 -1 -1 -3 -1 -3 -2 -2 -8 -1 0 2 0 -5 0 3 -3 4 3 -3 4
-3 -3 1 2 -1 2 -2 -3 -1 -2 -2 0 -2 1 -1 -3 1 1 -5 0 0 1 0 0 -9 0 -2 0 -6 8 3 1 -7 3 -8 4
-2 -4 0 0 0 1 -1 -4 -1 1 -2 -2 -5 1 1 -2 -4 0 -1 2 -2 -2 -3 1 -1 -4 -5 3 -7 -4 -5 -8 4 0 -1 -4 4 5 -10 0
-2 -3 0 2 -1 2 2 -3 1 2 -2 -3 -3 0 3 -4 -5 -1 0 2 -3 -2 -3 1 -1 -4 3 2 -11 -2 -5 -8 6 -2 -2 -4 3 4 -6 -1
-1 -3 -1 0 0 1 0 -5 -1 0 -1 -1 -2 1 1 -4 -4 0 -2 0 -3 -2 -2 0 0 -4 6 4 -9 -1 -2 -8 2 -4 -2 -3 6 10 -7 1
-2 -2 0 -1 0 2 -1 -3 -2 2 0 -2 -2 -1 -4 -4 -2 -1 -4 -2 -2 0 5 -7 2 6 -10 4 -2 -6 1 -4 -4 -4 6 9 -8 3
-2 0 -1 0 -3 3 -1 -3 -2 0 -1 -1 -3 0 1 3 -2 -2 -1 -2 -1 -1 -6 0 2 -7 0 -1 -6 1 -1 -1 -7 6 6 -9 1
-2 -1 0 -1 -1 3 -1 -2 -2 1 -3 -2 -3 0 1 3 -2 -4 0 1 -4 0 0 0 2 -7 -4 -5 -1 -2 -9 2 -2 -1 -9 4 3 -5 -4
-2 -1 0 0 -1 2 0 -4 -1 0 -2 -1 -2 -2 -2 -2 -2 0 -3 1 -2 0 0 -1 -7 3 -4 3 -6 -1 6 -6 1 -6 4 3 -5 -7
-3 -1 0 1 -1 0 -1 -4 -1 1 -3 -1 -1 3 0 -2 -2 -3 0 -1 -4 -1 -2 -2 -5 -3 -5 6 -8 5 -6 -2 3 -2 5 -4 2 4 -1 -4
-4 -1 1 -1 -1 -2 0 -4 1 1 -4 -3 -3 0 -1 -4 -4 -3 0 -1 -2 -2 -3 -1 2 -4 -3 4 -9 6 -7 -2 0 1 5 -2 0 5 0 -4
-2 -1 1 -1 1 1 -3 -2 0 1 -4 -4 -1 2 1 -3 -2 -2 -1 -1 -4 -1 -2 -2 0 -6 -1 0 -1 4 -6 -2 -3 2 5 -1 0 8 -2 -3
-2 -3 3 -1 2 0 -1 -3 -2 0 3 -2 2 2 1 -3 4 -3 -1 1 1 0 -2 4 -8 -4 -4 2 1 -6 5 1 5 1 -3 2 0 -3 -5
-3 -1 1 -1 0 -1 0 -3 -2 -3 1 2 0 2 -4 -1 0 -2 2 -3 -1 2 -12 -6 0 0 0 -1 3 -3 4 1 -1 1 -7 -3 -4
-1 -1 1 -1 0 0 -1 -2 -1 -1 -3 -2 0 2 -1 -3 -1 -1 -2 -2 1 -1 -11 -7 -7 4 -0 1 2 0 3 -2 4 -6 -1 -2
-2 -1 0 -2 -3 0 -1 -1 -1 2 -2 3 3 0 -3 -5 2 -1 -1 -3 2 0 2 -9 -11 -6 0 2 0 5 -1 0 3 -1 0 -8 -2 -2
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-1 -1 -1 -2 -1 -3 0 0 0 1 -3 -3 -2 -1 2 -4 -3 0 -2 -1 -3 -1 -2 3 0 7 -3 2 -6 -8 0 4 0 -2 5 4 -6 1 -2 -6
-3 -1 2 -1 -1 -1 0 0 0 1 -4 -3 -1 -1 1 -2 -3 -4 0 -2 -3 2 -1 0 -2 6 -1 1 -9 -8 2 3 -3 -1 3 -4 -4 2 -1 -7
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-3 1 -2 0 0 -1 -2 -1 1 0 -1 -2 1 2 -3 -3 -3 -1 0 -1 0 1 1 -1 0 0 1 -2 4 8 -4 -5 2 -5 -6 -4 3 -1 -9
-2 2 -1 -1 0 -2 -1 -2 1 -1 -5 -4 3 1 -6 -2 -1 -1 -1 -2 0 2 3 0 3 -1 -4 -4 0 -1 5 2 -3 -6 -8 0 2 -10
-2 -2 -1 -1 1 -2 -1 -2 -1 -3 -3 -4 0 -4 4 -2 -1 -1 -1 1 2 -1 -1 3 4 -3 2 -2 -1 4 -4 -5 -7 -3 4 -10
-3 -3 1 -1 3 -5 -1 -1 1 0 -4 -2 -4 2 -1 -2 -3 -1 1 -1 -4 -3 0 0 -7 0 -6 3 3 7 5 -1 -2 -2 -6 3 -6 -2 0 -7
-2 -2 1 -1 3 -1 -2 -2 0 -1 -2 -1 -1 2 -1 -1 -3 0 2 -1 -4 -1 -1 -2 -1 -2 -5 3 3 6 5 2 -1 0 -5 2 -4 -2 2 -9

Digitized Sound

- 3 seconds of Homer is about 30,000 numbers
- What can we do with these numbers?
 - store them (CD, hard disk drive)
 - transmit them (over the Internet)
 - CHANGE SOME OF THEM!

Hide the Message in Homer

Change some of the number's in Homer's voice file into the secret message numbers

– we only have to change

30,000

13 5 5 20 27 13 5 27 2 5 8 9

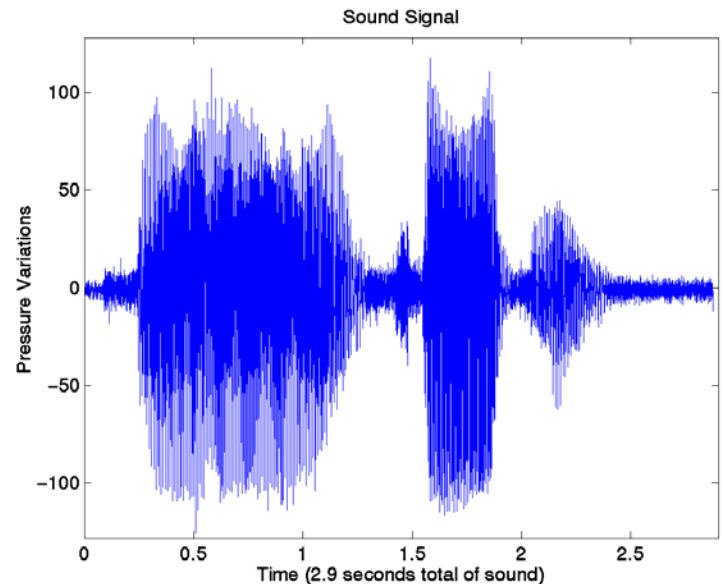
14 4 27 20 8 5 27 18 5 19 20

1 21 18 7 14 20 27 1 20 27 13

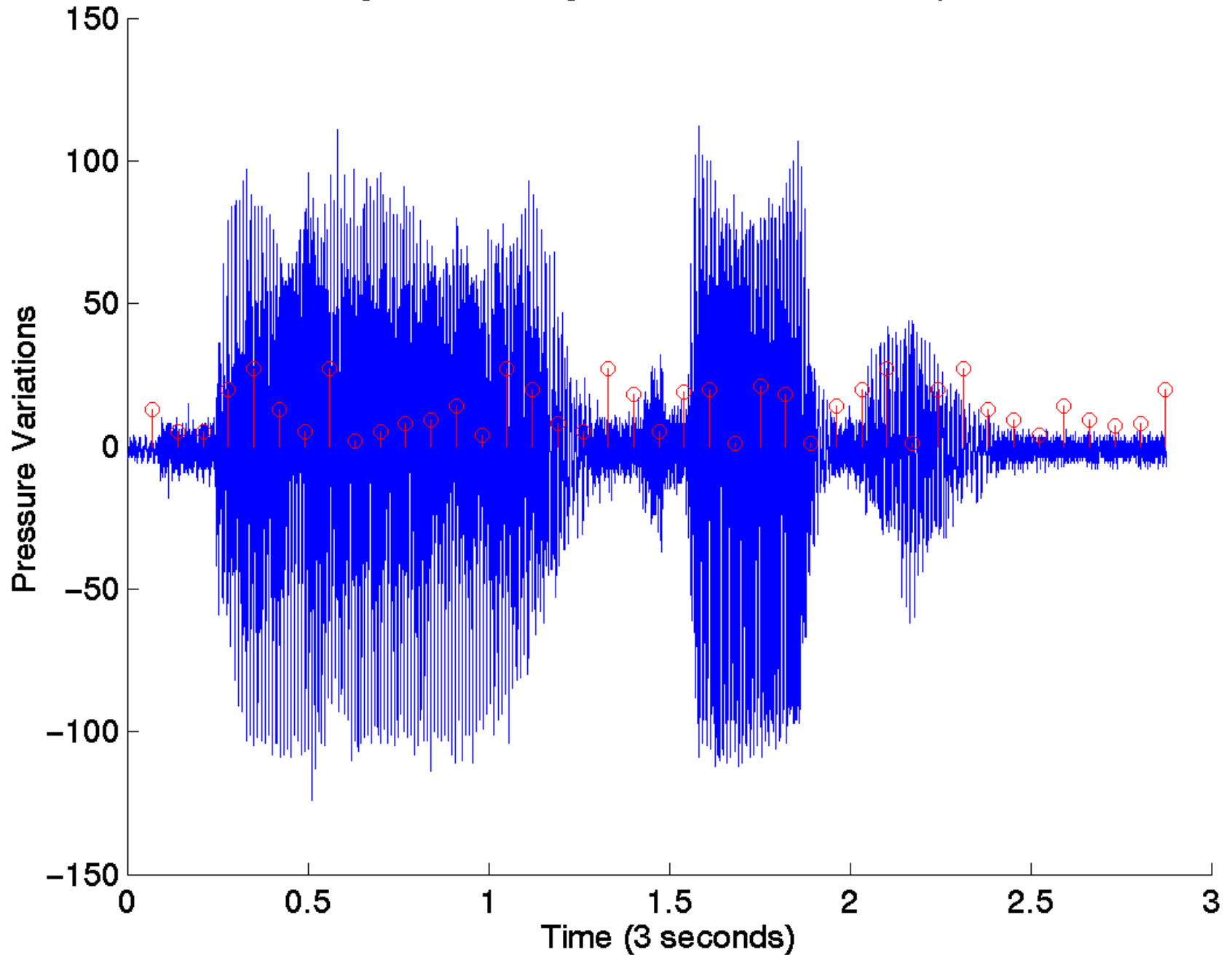
9 4 14 9 7 8 20

– can you tell that there is

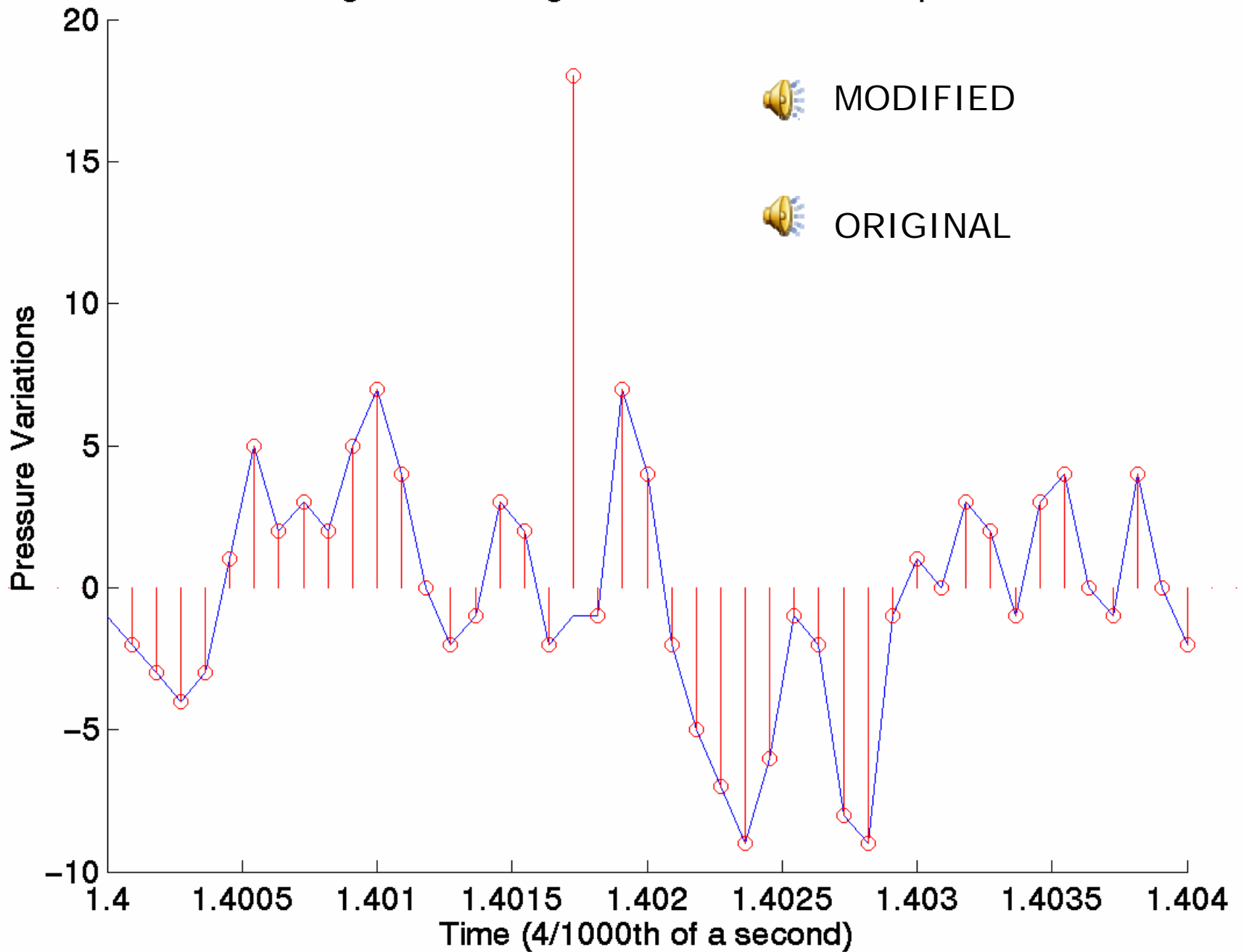
by listening to the sound



Digital Sound Signal and MODIFIED Samples



Digital Sound Signal and MODIFIED Samples



Longer Message (1,926 letters)

the federal reserve left short term interest rates unchanged at one percent today noting in a statement that hiring has lagged and suggesting that the central bank remains uneasy about the nations weak job market todays decision had been widely expected by analysts and investors but it reinforced expectations that the fed will refrain from raising interest rates until much later this year or perhaps even next year the central banks target for the federal funds rate the rate charged on overnight loans between banks has been at its lowest level in forty six years ever since last summer alan greenspan chairman of the federal reserve has warned that todays rates are too low to be sustainable indefinitely at its last meeting on jan twenty eight the central banks policy setting committee retreated from its open ended commitment to keep rates low for a considerable period but fed officials have made it clear they are worried and puzzled about the persistently low level of job creation and the stubbornly high level of unemployment they have also emphasized that inflation remains at extraordinarily low levels, even though the united states economy has been expanding at an annual rate of more than four percent in its statement today the federal open market committee said that the economy continues to expand at a solid pace and it reiterated its previous view that the risks of inflation are almost equal with those of of deflation the new statement hinted at slightly more pessimism than last month about the jobs market although job losses have slowed new hiring has lagged the committee said as before the central bank said that increases in consumer prices are muted and expected to remain low it also reiterated its view that there is still slack in the nations use of its resources meaning that a relatively low proportion of the nations factory capacity is being used and that the job market is still sluggish

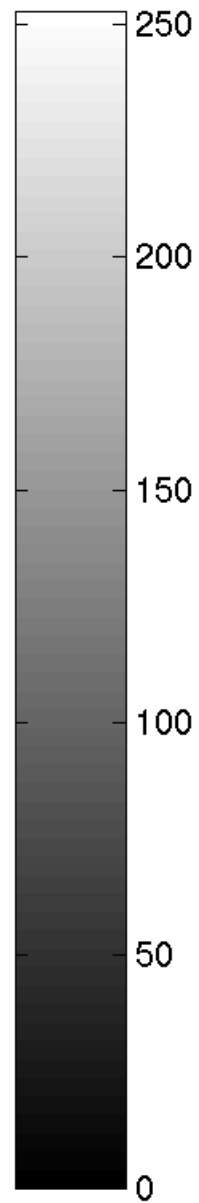
ORIGINAL

MODIFIED

Digital Images

- A digital image is a grid of tiny squares, called pixels
- Each pixel is assigned a number
- A pixel's number determines its 'color'

537 x 358 pixels



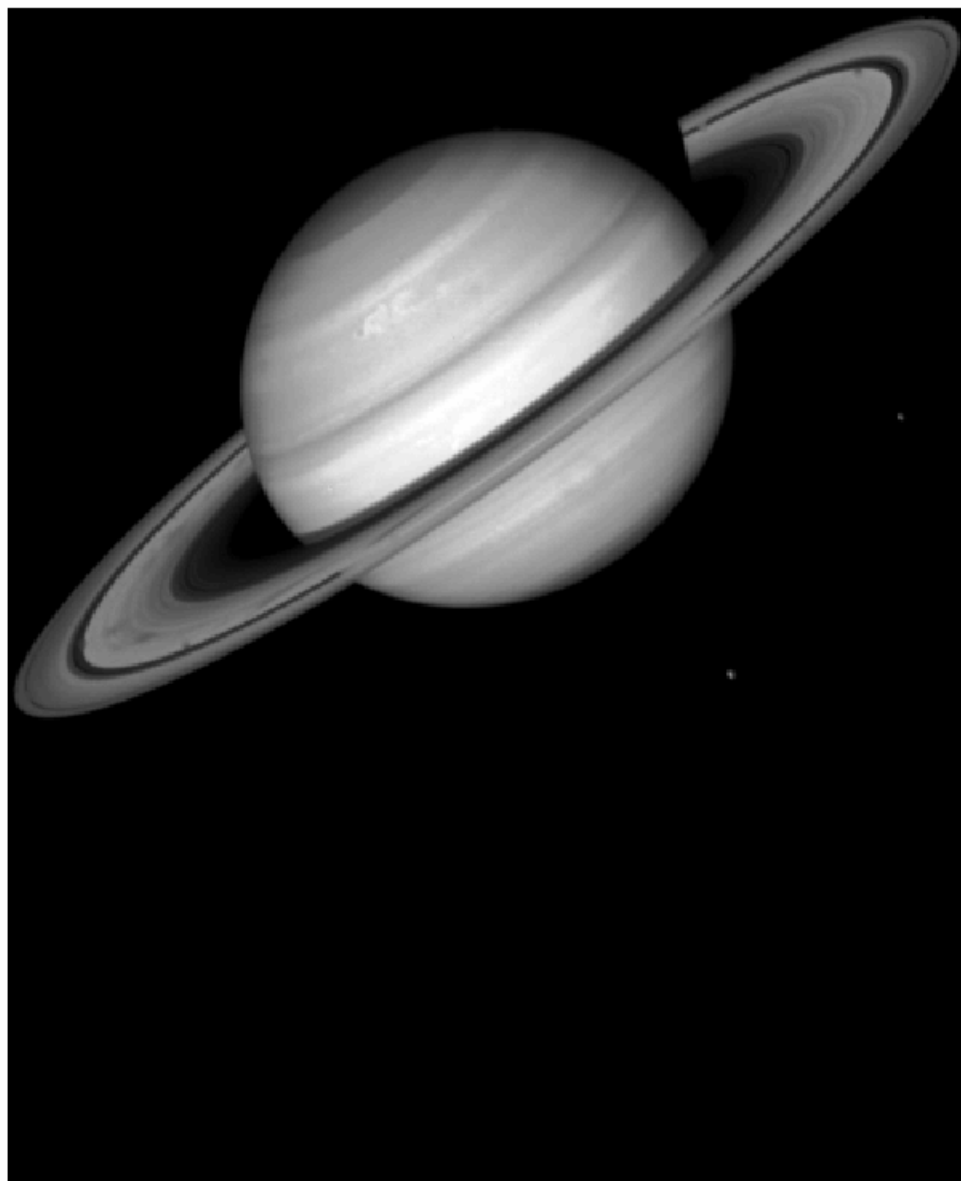
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3 3 4 4 5 2 2 6 9 10 5 5 10 7 8 4 9 9 2 4 5 7 5 5 9 3 4 9 13 3 6 3 4 14 9 5 6 10 2 5
6 3 4 11 4 4 4 3 1 2 4 3 8 4 9 3 12 8 5 3 7 5 5 11 10 3 5 6 7 4 7 5 6 10 12 7 7 5 8 4
7 3 8 11 11 8 3 4 4 8 6 4 5 3 16 5 6 6 9 3 7 8 12 4 11 3 6 7 6 13 9 8 3 6 3 7 7 2 4 4
2 4 4 5 5 2 5 12 5 14 10 3 10 12 8 3 6 7 5 9 9 4 8 2 5 8 5 5 3 5 7 9 3 8 8 1 6
7 6 2 3 6 2 8 8 7 3 8 3 3 4 10 3 5 5 7 2 9 7 9 5 5 8 2 2 3 7 8 9 10 5 8 5 8
8 4 2 7 9 12 10 4 2 4 3 4 6 10 5 6 7 4 5 6 11 10 5 10 7 2 10 2 8 4 3 6 3 8
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10 8 6 4 3 9 5 6 1 8 11 6 3 5 9 5 11 6 7 8 5 4 7 7 9 3 18 5 12 7 6 4 2 5 7 9 2 3 7 4
4 2 2 5 3 4 6 8 3 3 6 4 3 7 9 4 7 6 3 3 3 5 6 2 8 3 7 12 10 12 2 10 5 5 7 8 4 1 5 5
6 3 10 2 3 4 3 4 5 3 1 3 2 3 6 4 5 7 5 8 5 7 7 8 4 3 3 8 9 15 5 5 6 8 2 6 5 3 6 9
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9 7 4 3 3 1 9 6 7 4 4 5 7 5 4 12 12 5 3 10 8 3 4 3 3 4 4 2 9 6 5 7 7 8 5 5 8
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5 3 3 5 5 6 8 2 12 4 4 8 2 6 4 5 4 9 6 6 9 4 3 10 4 8 8 2 7 2 7 2 8 5 0 3 10 4 5 9
3 12 13 11 3 8 7 2 12 4 3 7 3 6 4 7 8 7 8 7 7 6 4 8 10 6 6 10 6 9 3 3 4 6 2 4 7 8 10 14
4 9 13 4 9 3 3 5 8 3 7 6 1 9 4 5 6 6 7 4 3 4 4 5 6 5 7 12 7 3 2 2 5 11 4 5 5 5 12
3 9 1 5 7 5 3 8 4 1 2 6 7 6 4 7 6 6 8 12 7 6 3 7 8 0 5 5 5 3 5 6 11 2 6 4 2 9
2 9 3 8 1 4 6 0 1 2 9 2 3 12 10 3 9 9 7 6 8 3 5 10 9 9 11 4 3 4 5 8 2 3 8 2 5
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4 8 8 7 14 5 1 2 3 8 7 4 10 8 4 9 10 4 5 3 4 9 6 1 3 6 3 1 2 8 5 4 5 10 11 10 10 1 4 3
6 11 2 4 15 11 5 5 10 5 3 1 11 3 5 8 8 2 2 3 6 11 5 6 5 6 8 4 5 5 3 6 9 6 5 7 7 3 9 3
7 7 4 3 3 3 8 1 7 2 10 6 4 6 5 6 4 3 2 6 5 8 7 3 7 5 8 5 7 3 2 2 6 5 2 9 5 4 11 3
3 6 4 3 2 3 14 0 4 3 9 5 6 6 7 6 3 3 2 11 6 7 7 3 5 6 3 5 8 3 3 2 2 8 5 16 3 3 8 3
5 6 5 2 5 12 3 4 6 2 2 7 5 5 7 3 3 7 10 6 8 4 3 7 6 5 4 3 3 12 7 3 4 10 5
5 3 3 2 6 4 3 11 3 4 3 5 1 5 5 8 2 6 4 3 14 6 4 3 3 4 4 3 10 2 5 5 7 6
9 12 3 9 6 5 5 3 4 4 3 4 4 10 5 5 5 5 6 5 6 13 9 7 6 3 7 5 4 5 8 3 12 3 7 2
4 4 4 13 1 2 8 1 2 2 3 7 3 6 4 4 2 5 4 6 11 7 7 2 6 15 5 2 10 8 5 5 8 11 6 9
4 8 3 6 5 4 8 4 3 6 1 9 3 7 4 7 7 2 4 8 10 3 2 10 5 5 3 7 4 6 5 4 9 7 5 3 3 11 5 7
5 7 3 5 5 6 9 8 2 2 4 3 4 7 7 12 6 7 5 10 12 8 6 6 4 3 13 12 5 4 3 8 6 7 3 5 3 7 4 4

Hiding Images within Images

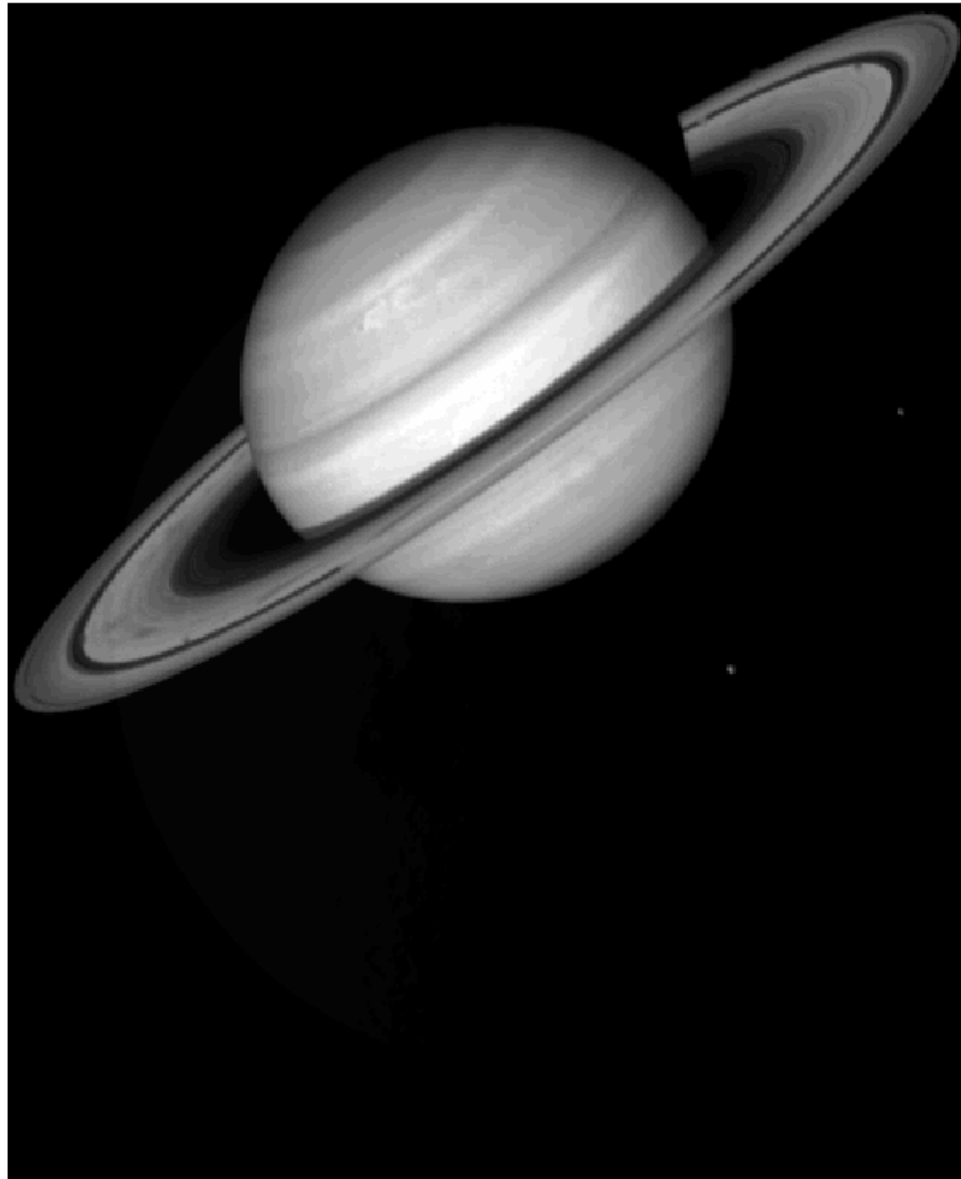
Hide an image of the moon in an image of Saturn.

- “How much” of the moon do we want to put into Saturn?

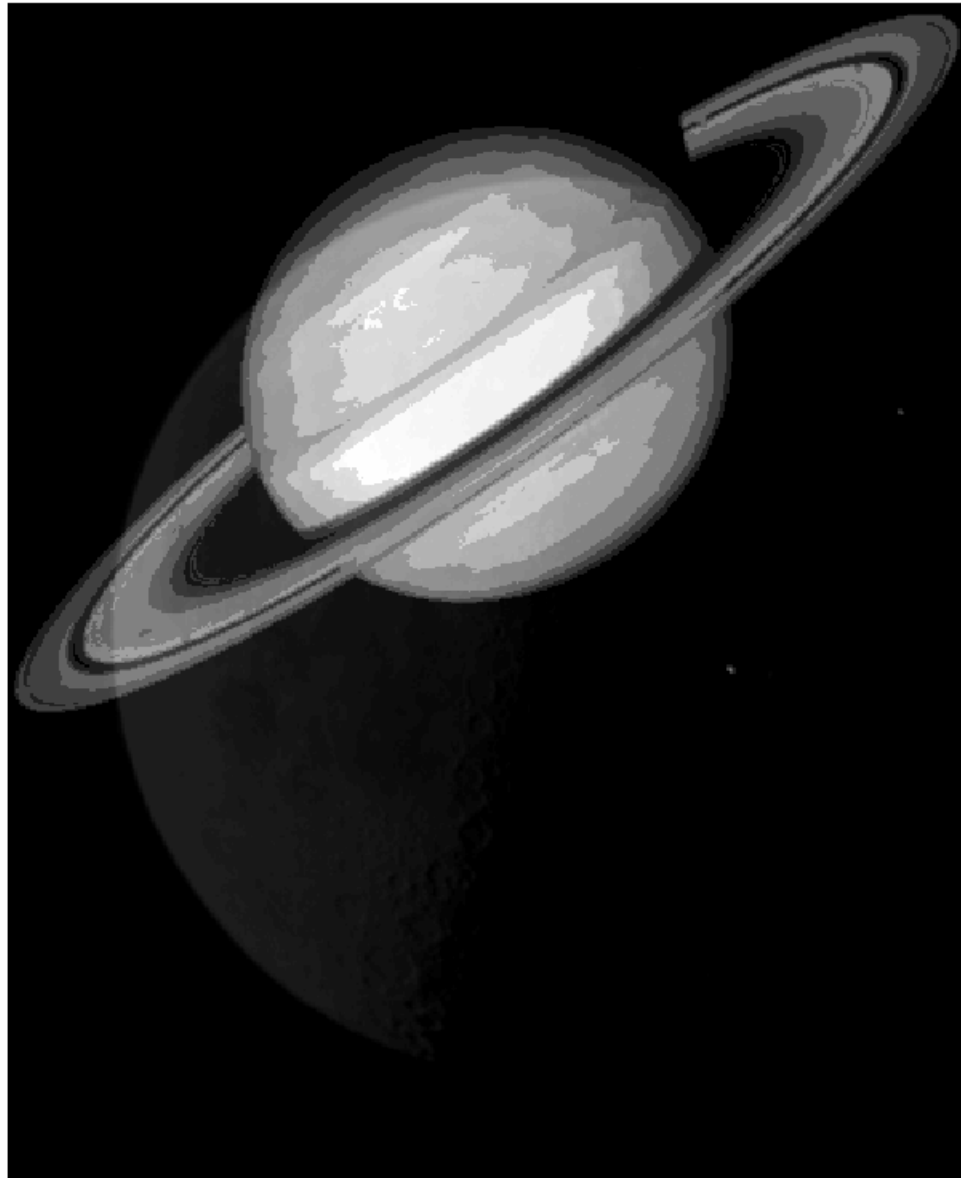
1 bits/pixel of Moon hidden in Saturn



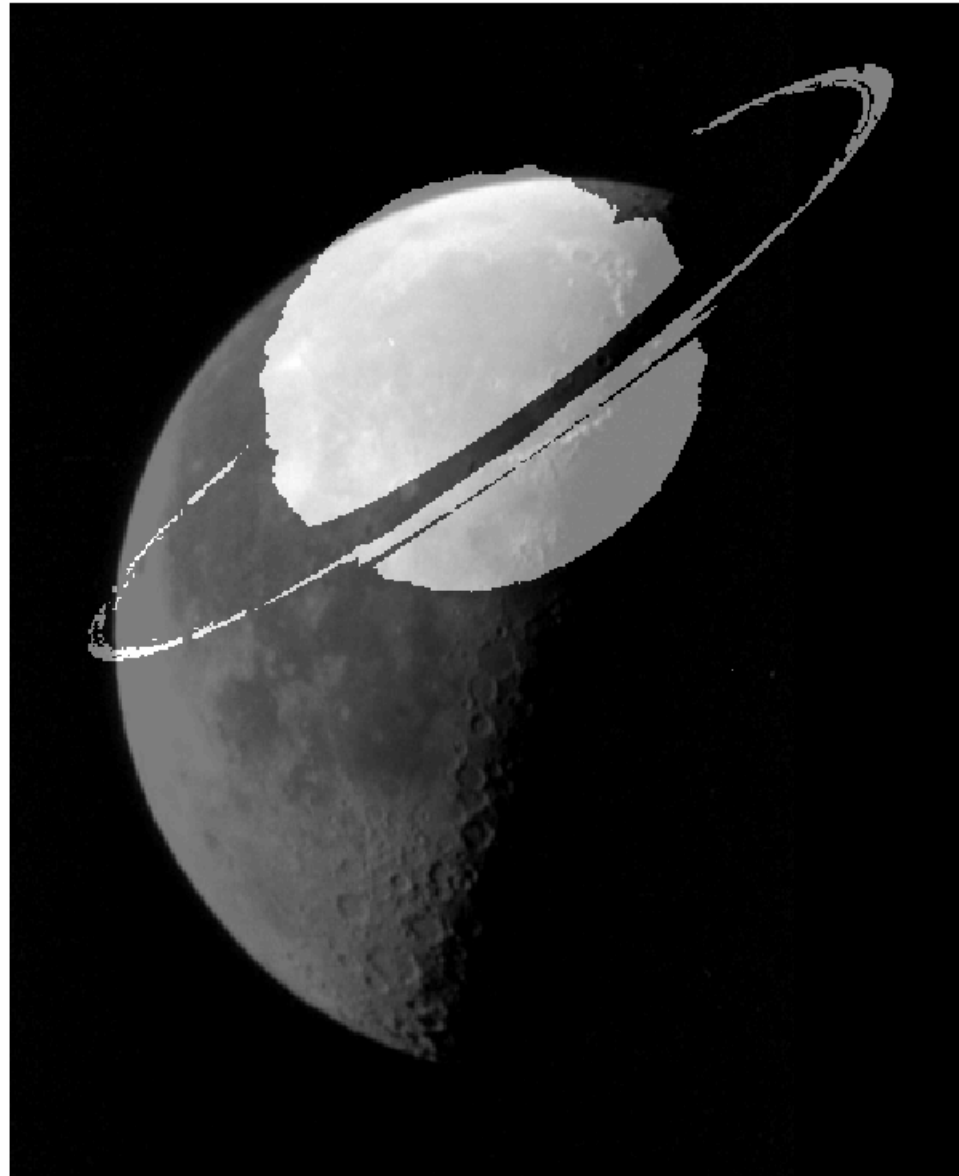
3 bits/pixel of Moon hidden in Saturn



5 bits/pixel of Moon hidden in Saturn



7 bits/pixel of Moon hidden in Saturn

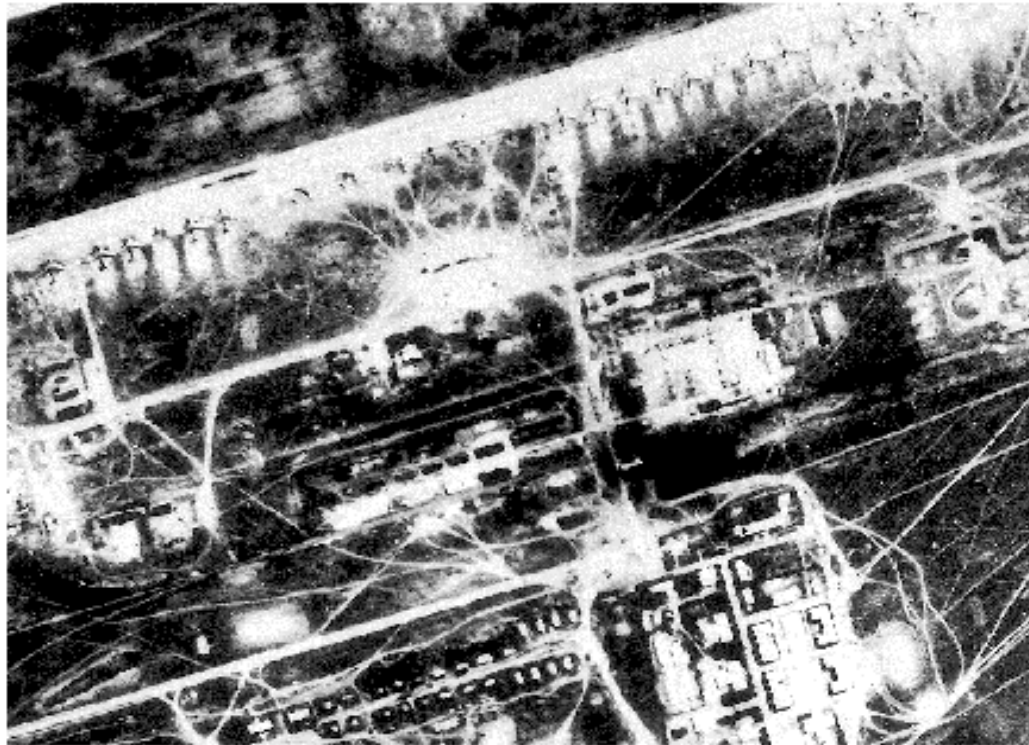


More Picture Hiding



Renoir

Covert Data



Long-range Aviation Airfield

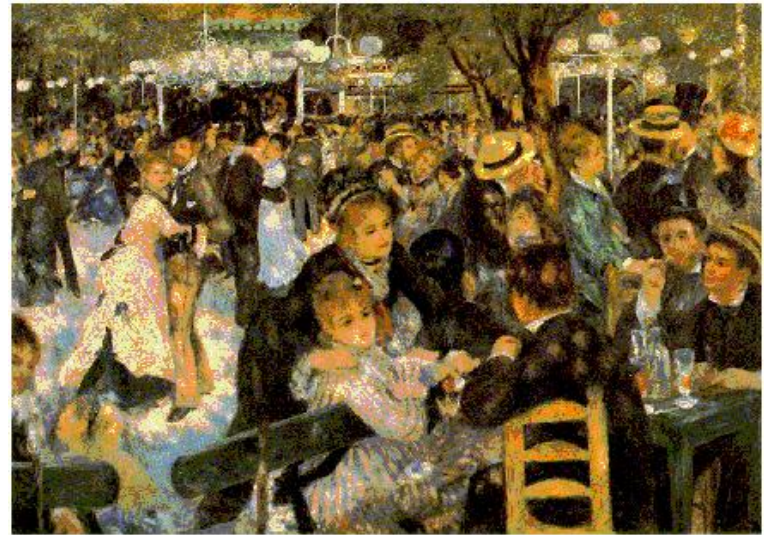
'Composite' Image



Undetectable (unless aware)



Original



Composite

Observations

- It is easy to hide small digital messages inside of larger ones
- If you try to hide too much, it doesn't work very well

Working to provide as much hidden information as possible without detection (e.g., distortion-compensated quantization index modulation – QIM)

Digital Fingerprinting and Traitor Tracing



- Digital fingerprinting
 - Authenticate
 - Who bought/sold/ . . . *Veil Interactive*
 - Printers/copiers
- Mark copies to find out where the data are being compromised

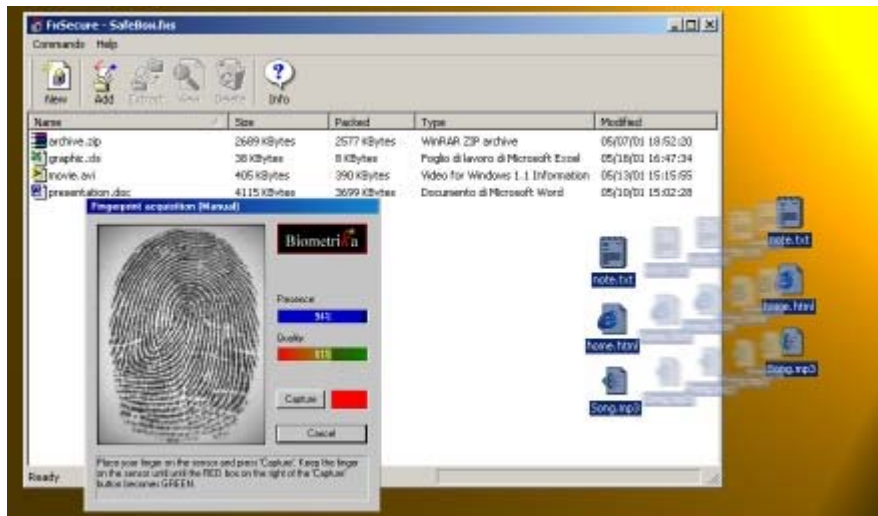
DIGIMARC

SIGNUM
TECHNOLOGIES

CST
Center for Security
Technologies

Embed Biometric into Document

identity systems group ^{inc.}
Helping government secure the future



How Good is Steganography?

This process can hide data perfectly so that no one, not even the ‘good guys’, can find it



“Bootleg copies of Oscar-nominated movies showing up on Internet”

AP January 14, 2004

- “The Last Samurai,” “Something's Gotta Give,” “Cold Mountain,” “House of Sand and Fog”

– “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.”

– “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.”



Securing Documents



- Determine security goal
- Assess cost and performance
- Choose technology
- Understand game theoretic aspect
- Integrate/implement system

Should be able to provide useable,
long-term solution

cst.wustl.edu

