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Computer Forensics and Intrusion Analysis

Fuzzy Hashing

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Introduction

- Interactive Presentation
  - The answer is always “it depends”
  - Ask me anything at any time
- Computer Forensics Engineer
  - Link between academics and practitioners
- Former AFOSI agent

- Tool Developer
  - foremost, md5deep, FRED

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Outline

- Introduction
- The Joy of Hashing
- MD5 Completely Explained [Abridged]
- Piecewise Hashing
- Rolling Hash
- Fuzzy Hashing
- Matching
- Demonstration
- Issues
- Future Research

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The Joy of Hashing

- Hashing reduces any input to a fixed size output
- Lots of different hashing algorithms
  - Most are not suited for forensics
- We use cryptographic hashing algorithms
  - MD5, SHA-1, Whirlpool, Tiger
  - These are great for finding identical things
  - Can't be used to find similar things

What is "Similar"

- This is a hard question
- "How are you" vs. "How are y0u"
- Blade Runner vs. The Fifth Element
  - Plot
  - Themes
  - Motifs (e.g. Messages at lunch counter)
  - Streams of ones and zeros

Streams of Ones and Zeros

- For our purposes, searching for file homologies
  - Files with large sequences of identical ones and zeros
- Two Microsoft Word Documents with different metadata

```
C:\>md5deep -b *.doc
63bb20b0df871ae390af2af0b0a33248  BusinessPlan.doc
618e7bf2232d7f29406246c692e4dd10  StolenPlan.doc
```

Disclaimer

- I didn't invent this math
- Originally Dr. Andrew Tridgell
  - Samba
  - rsync was part of his thesis
  - Modified slightly for spamsum
    - Spam detector in his "junk code" folder
- Discovered by G.
  - User report that rsync confuses similar Word documents

MD5 Explained

How MD5 (roughly) works:

3. Start with an initial state
4. Look at fixed size block of input
   - Do mathy stuff with current state and block
   - Get new state
5. Advance to next block of input
6. Repeat steps 2 and 3 until out of input blocks
7. Ending state is the hash

MD5 Explained

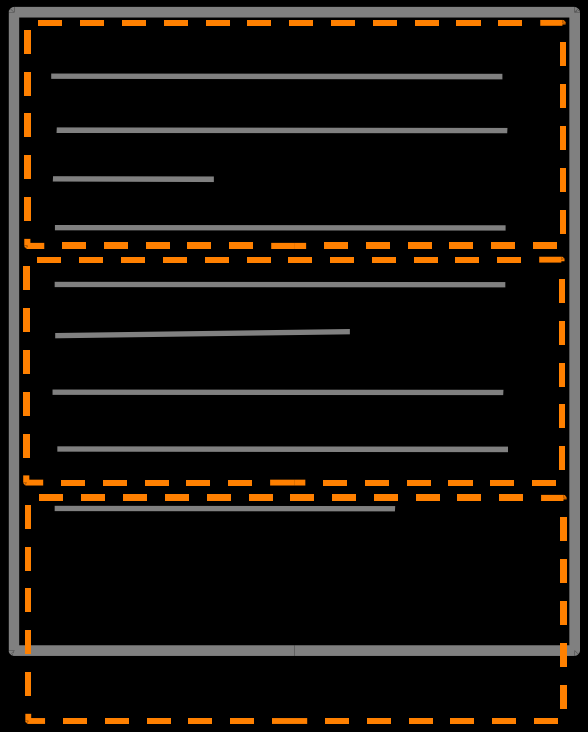
- If you change one bit in the middle, you change the next state
- Which ends up changing the end result

- Is this a good thing or a bad thing?

?

Piecewise Hashing

- Developed for integrity during imaging
- Divide input into fixed sized sections and hash separately
- Insert or delete changes all subsequent hashes



3b152e0baa367a8038373f6df

40c39f174a8756a2c266849b

fdb05977978a8bc69ecc46ec

Rolling Hash

- It would be nice to set boundaries such that
  - Insertions and deletions are contained within a block

Rolling Hash

- A different kind of hash function
- Produces a pseudorandom output for every position in a file
  - Depends only on last few bytes
  - Lots of academic work on these
  - Just mathy tricks

```
F o u r   s c o r e   ->  83,742,221

F o u r   s c o r e   ->       5

F o u r   s c o r e   ->    90,281
```

Rolling Hash

To update state (c,x,y,z,window) for a byte d:

y = y − x

y = y + size * d

x = x + d

x = x − window[c mod size]

window[c mod size] = d

c = c + 1

z = z << 5

z = z XOR d

return (x + y + z)

Rolling Hash

- We use the rolling hash to generate block boundaries
- Select some values as trigger points
- When we hit a trigger point, end the block

- Example
  - Excerpt from "The Raven" by Edgar Allan Poe
  - Triggers on ood and ore

Rolling Hash

Deep into the darkness peering, long I stood there, wondering, fearing

Doubting, dreaming dreams no mortals ever dared to dream before;

But the silence was unbroken, and the stillness gave no token,

And the only word there spoken was the whispered word,

Lenore?, This I whispered, and an echo murmured back the word,

"Lenore!" Merely this, and nothing more

Rolling Hash

Deep into the darkness peering, long I stood there, wondering, fearing

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Rolling Hash

Deep into the darkness peering, long I stood

there, wondering, fearing Doubting, dreaming dreams no mortals ever dared to dream before

; But the silence was unbroken, and the stillness gave no token,

And the only word there spoken was the whispered word,Lenore

?, This I whispered, and an echo murmured back the word,"Lenore

!" Merely this, and nothing more

Rolling Hash

- How do we choose the triggers?
  - Chosen randomly, before reading the file
  - Based on the size of the input file
  - Really just a set of numbers
  - Has nothing to do with type of input data

Fuzzy Hashing

- Combine Rolling Hash with a Traditional Hash
- Use Fowler/Noll/Vo (FNV) hash
  - That's what Tridgell did
  - Faster and less complex than MD5
  - We're only using a small part of the result

- Start reading file, compute Rolling and Traditional Hashes
- When Rolling Hash triggers
  - Record LSB of Traditional Hash value
- When finished, combine LSBs to make signature

Rolling Hash

Deep into the darkness peering, long I stood

there, wondering, fearing Doubting, dreaming dreams no mortals ever dared to dream before

; But the silence was unbroken, and the stillness gave no token,

And the only word there spoken was the whispered word,Lenore

?, This I whispered, and an echo murmured back the word,"Lenore

!" Merely this, and nothing more

Rolling Hash

Deep into the darkness peering, long I stood — 28163

there, wondering, fearing I AM THE LIZARD KING! Doubting,
dreaming dreams no mortals ever dared to dream before — 82910

; But the silence was unbroken, and the stillness gave no token,

And the only word there spoken was the whispered word,Lenore — 37

?, This I whispered, and an echo murmured back the word,"Lenore — 14541021 3

!" Merely this, and nothing more — 738210

Matching

Signature 1: 3 2 7 3 0

Signature 2: 3 0 7 3 0

- Edit Distance
  - Number of insertions, modifications and deletions to turn Signature 1 into Signature 2.
  - For the example above, the edit distance is one.
- Signatures (and thus files) match when the ratio of the edit distance to the length is small

Demonstration

- Word Documents

Rolling Hash

Deep into the darkness peering, long I stood 28163

there, wondering, fearing Doubting, dreaming dreams no mortals ever dared to dream before 491522

; But the silence was unbroken, and the stillness gave no token, 57

And the only word there spoken was the whispered word,Lenore

?, This I whispered, and an echo murmured back the word,"Lenore 145410213

!" Merely this, and nothing more 738210

Demonstration

WARNING:

EXPLICIT IMAGERY

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Demonstration

Demonstration

- Needle in a haystack

Known kitty porn

MATCH

Demonstration

- Does not match similar looking images

Known kitty porn

no match
(00000380.JPG)

Demonstration

- File header

Known kitty porn

MATCH

Demonstration

- File footer

Known kitty porn

MATCH

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Demonstration

- Source code reuse

Issues

- Does not work for similar looking graphics
  - For that use imgSeek http://www.imgseek.net/
- Confused by many small changes throughout input
- Unable to handle cropping, resizing, and other edits
- Computationally intensive
  - 7-10 times slower than MD5
- No way to sort signatures
  - Must compare each input to all known signatures

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Issues

- Matching via Fuzzy Hashing is not proof!
  - Similar does not mean identical
- An excellent basis for further examination
  - Probable cause

"I ran a program called "ssdeep" that uses Context Triggered Piecewise Hashing (aka "Fuzzy Hashing") on SUBJECT's hard drive and a set of signatures of known child pornography. The program identified 417 files on SUBJECT's hard drive that matched the known images of child pornography. The output of the program, demonstrates that a significant majority if not the entirety of each matching file is identical to the known child pornography image that it is said to match.

Based on the presence of child pornography on SUBJECT's hard drive, the Government requests to search SUBJECT's primary residence…"

Future Research

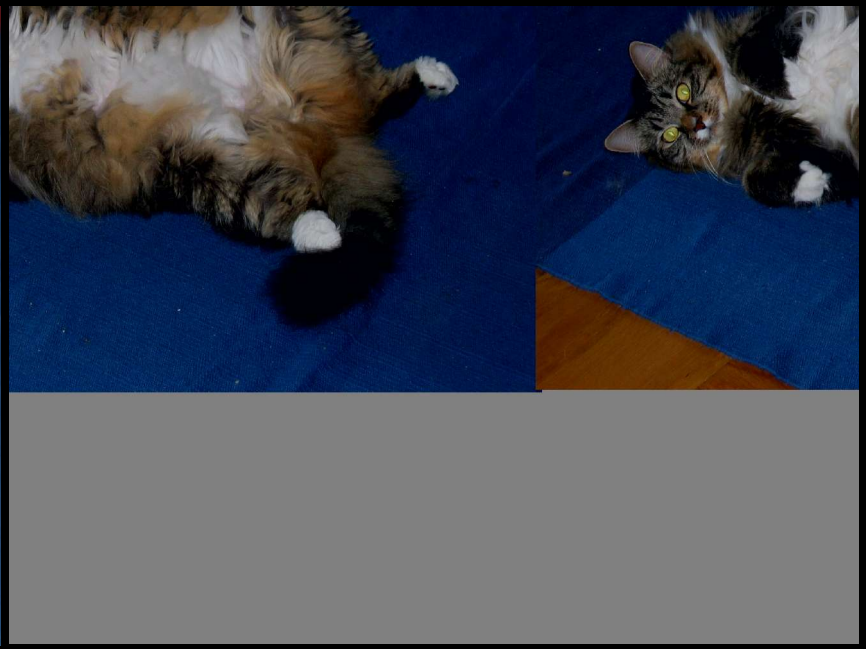
- Need hashes of known files
  - Hash sets like NSRL or Hashkeeper
  - How much information to record?
    - File size, content?

- File Footer Reconstruction
  - Record headers when making signatures
  - Append recovered footers

Future Research

- File footer Reconstruction

Known kitty porn



File header with footer appended

Future Research

- Finding footers and middles
  - Current carvers require true footer
  - Encase, iLook, Foremost, Scalpel, etc.
- Find blocks that are "JPEGy" or "GIFy"
  - Lots of academic research
  - No practical tools
- What makes things similar?
  - Lots of research to date
  - Most focuses on plagiarism by CS students

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Conclusion

- Fuzzy Hashing allows examiners to find documents that are similar but not quite identical.
- ssdeep is Free and Open Source
  - http://ssdeep.sf.net/
  - Windows executable and source code
  - Graphical Front End now available!
- Questions? Write to me at jesse.kornblum@mantech.com.
  - I am always available for LE

Questions

Jesse Kornblum

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