Security Aspects of Fuzzy Hashing

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- Bachelor Degree at Hochschule Mannheim in March 2009
- Master Degree at Hochschule Darmstadt in February 2011
  - IT-Security
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- Since March 2011 Research Student at CASED
  - Center for Advanced Security Research Darmstadt
- Publications:
  - User Survey on Phone Security and Usage (BioSIG Sept. 2010)
  - Security Aspects of Piecewise Hashing in Computer Forensics (Accepted at IMF Mai 2011)
Motivation [1/2]

▶ Main question: Is it possible to identify similar files based on a fingerprint, which depends only on the files’ byte structure?

▶ Cryptographic hash functions follow the avalanche effect: Changing a bit in the input affects $\approx 50\%$ of the output bits $\rightarrow$ no match

▶ Fuzzy hashing promises to overcome this problem and discover similarities based on fingerprints.

▶ Question addressed in this talk: How reliable are the results of Kornblum’s approach for fuzzy hashing with respect to an active adversary?
Motivation [2/2] - Applications

1. Forensics (on the file level): Detect similar files
   ▶ Blacklisting:
     ▶ Detect manipulated suspicious files
     ▶ Find fragments of suspicious data
   ▶ Whitelisting: Find variants of unsuspicious files

2. Biometrics: Template protection

3. Malware: Detect obfuscated malware (e.g. metamorphic malware)

4. Junk mail detection
Agenda

Kornblum’s Fuzzy Hashing

Security Aspects

Conclusion

Contact, Discussion
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Fuzzy Hashing by Kornblum

- *Context Triggered Piecewise Hashing* (CTPH) (software named ssdeep)

- Developed in 2006 based on spamsum-algorithm from A. Tridgell

- Key elements:
  - Block size
  - Rolling hash
  - Traditional hash / piecewise hashing
  - Signature

- Pioneer: *dcfldd*
  - Blocks had a fixed size
  - Non-propagation = yes  alignment robustness = no
Kornblum’s Fuzzy Hashing

Key Elements

- **Block size:** $b$
  - $b_{\text{init}} = b_{\min} \cdot 2^{\lfloor \log_2 \left( \frac{n}{s \cdot b_{\min}} \right) \rfloor}$

- **Rolling Hash** at position $p$ in the file:
  - $r_p = F(n_{p-s+1}, n_{p-s+2}, \ldots, n_p)$
  - Allows to compute $r_{p+1}$ cheaply from $r_p$ by removing the influence of $n_{p-s+1}$ and including the new byte $n_{p+1}$

- **Traditional Hash / Piecewise Hashing:**
  - Currently, ssdeep makes use of Fowler/Noll/Vo (FNV)
  - Alternative hash functions are possible (e.g. SHA-1, MD5)
Kornblum’s Fuzzy Hashing

Workflow

last Trigger Seq.

Window

_window

chunk

\[ \text{FNV-HASH (HELLO_MY_WOR)} = 32234013 \]
\[ 32234013 \% 64 = 5 \]
\[ 5 = E \]

Signature: \ldots X E \ldots \]
Kornblum’s Fuzzy Hashing

Kornblum Signature

- 2 Signatures:
  - Signature 1: Using block size $b$ (at most 64 characters)
  - Signature 2: Using block size $2b$ (at most 32 characters)

- Sample Kornblum signature of test-file1:

  1. 24:T0tUHZbAzIaFG91Y6pYaK3YKqbaCo/6Pqy45kwUnmJrrevqw+oWluBY5b32TpC0:
     T0tU5s7ai6ptg7ZNcqMwUArKvqfZ1MC0,"/test-file1"
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Characteristics of Kornblum’s Implementation

- Signature comparison:
  - Only signatures with the same block size or within a factor of 2 can be compared
  - A successful match needs at least *one common substring in the signature of length 7*
  - A signature has at most 64 characters

- If block size is known, we can calculate trigger sequences:
  - Easy observation: A trigger sequence for \( b \) is also a trigger sequence for all block sizes \( \frac{b}{2^k} \)
  - Concatenation of trigger sequences yields signature characters (e.g. _MY_WOR in previous example)

- Attack type depends on the file syntax:
  - BMP / ASCII-files can be changed ‘everywhere’ (easily)
  - JPG / PDF-files allow a change of header information
Attacks?

What do we like to achieve?

1. **False negatives** for blacklisting $\rightarrow$ anti-blacklisting
   - Modified incriminated files are not detected by the blacklist although perceptual identical to the original known-to-be-bad file

2. **False positives** for whitelisting $\rightarrow$ anti-whitelisting
   - Incriminated files are modified to get a signature of a known-to-be-good file
   - Modified incriminated file is perceptual identical to the original known-to-be-bad file
Attacks for Anti-Blacklisting

- **Blow up a file**: Block size gets larger

- **Edit trigger seq.**: Block size gets different (unpractical)

- **Edit between trigger seq.**: Change one byte in every $7^{th}$ chunk

- **Adding trigger seq.**: Add several trigger seq. in the beginning of a file

- No semantic attacks like rotations, colour changes, ...
Anti-Blacklisting: Blow up a File

```bash
$ ls -la hacker_siedlung.jpg
-rw-r--r-- 1 user user 68650 2011-02-23 13:57 hacker_siedlung.jpg

$ dd if=/dev/urandom of=hacker_siedlung.hacked.jpg bs=1 count=280000
 280000+0 records in
 280000+0 records out
 280000 bytes (280 kB) copied, 1.39661 s, 200 kB/s

$ dd if=hacker_siedlung.jpg of=hacker_siedlung.hacked.jpg conv=notrunc
 69653+0 records in
 69653+0 records out
 69653 bytes (70 kB) copied, 0.20225 s, 344 kB/s

$ ssdeep -l hacker_siedlung.jpg hacker_siedlung.hacked.jpg
ssdeep,1.0--blocksize:hash:hash,filename
 1536:FLVoUaX+ns+6iAuLNdElztcCclGbn20CFN8DXg1BSXHaL++:
      F316ew331G2OMBSXa6+,"hacker_siedlung.jpg"
 6144:F6j0MBEjZML1AecfyqefFgQ5wDg+b7LQ7vZ0ubiPZ:
      F40Mq6i8qefFgU1Tsub6Z,"hacker_siedlung.hacked.jpg"
```
Attacks for Anti-Whitelisting

▶ *Edit between trigger seq.*: Change one byte in each chunk

▶ *Adding trigger seq.*: Add several trigger seq. in the beginning

▶ Difference: Adding information vs. editing information

▶ More computational power than for anti-blacklisting
Example: Editing Between Trigger Sequences
Example: Adding Trigger Sequences

- File need to be changed in the beginning
- One may use global trigger sequences:

<table>
<thead>
<tr>
<th>Trigger Sequence</th>
<th>Base64 Char.</th>
<th>Trigger Sequence</th>
<th>Base64 Char.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAD?Hp</td>
<td>9</td>
<td>AAAV?Hf</td>
<td>1</td>
</tr>
<tr>
<td>AAAD?Og</td>
<td>v</td>
<td>AAAf?Ft</td>
<td>p</td>
</tr>
<tr>
<td>AAAD?QT</td>
<td>7</td>
<td>AAAr?Xj</td>
<td>V</td>
</tr>
<tr>
<td>AAAJ?MW</td>
<td>P</td>
<td>AAAx?Fj</td>
<td>1</td>
</tr>
<tr>
<td>AAAJ?PJ</td>
<td>F</td>
<td>AAAx?OC</td>
<td>n</td>
</tr>
<tr>
<td>AAAJ?VO</td>
<td>Z</td>
<td>AAAx?tx</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3.1.: Sample pre-computed global trigger sequences and their corresponding Base64 signature characters

- Example: Insertion of concatenation of trigger sequences
Conclusion

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Summary

- CTPH from Kornblum does not withstand an active adversary with respect to
  - blacklisting
  - whitelisting
- Doubtful if piecewise hashing can fulfill the expectations of fuzzy hashing
  - Typically it is possible to flip one bit in each chunk
- In order to create a viable new fuzzy hash function, it will be necessary to find different approaches
Conclusion

Future Work

- Conduct a study if CTPH is applicable in forensics
- Clear definition of:
  - What we expect from a fuzzy hash function?
  - What is a metric for similarity?
- Find a more general approach, which also addresses images, videos, ... not only txt files
- Proof if this might be possible on byte level
- Otherwise new techniques might be needed:
  - E.g. first extract features then hash (e.g. FFT for images)
Thank you for your attention!

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