Security Aspects of Fuzzy Hashing

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- Master Degree at Hochschule Darmstadt in Februar 2011
  - IT-Security
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- Since March 2011 Research Student at CASED
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- 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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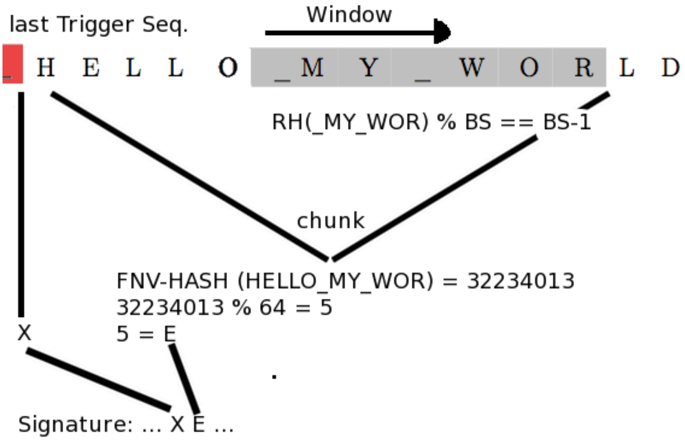
Fuzzy Hashing by Kornblum

- *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

Key Elements

- Block size: b
  - $b_{init} = b_{min} \cdot 2^{\lfloor \log_2 (\frac{n}{S \cdot b_{min}}) \rfloor}$
- 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)

Workflow


last Trigger Seq.
Window
_ H E L L O _ M Y _ W O R L D
RH(_MY_WOR) % BS == BS-1
chunk
FNV-HASH (HELLO_MY_WOR) = 32234013
32234013 % 64 = 5
5 = E
X
Signature: ... X E ...

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`:

```
24:TOtUHZbAzIaFG91Y6pYaK3YKqbaCo/6Pqy45kwUnmJrrevqw+oWluBY5b32TpC0:
      TOtU5s7ai6ptg7ZNcqMwUArKvqfZlMC0,"/test-file1"
```

Security Aspects

Kornblum's Fuzzy Hashing

Security Aspects

Conclusion

Contact, Discussion

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** → 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** → 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

```
$ 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+6iAuLNdElzt/CclGbn2OCFN8DXg1BSXHaL++:
   F3l6ew33lG2OMBSXa6+,"hacker_siedlung.jpg"
6144:F6jOMBEjZML1AecfyqefFgQ5wDg+b7LQ7vZOubiPZ:
   F4OMq6i8qefFgUlTsub6Z,"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

H E L L O _ M Y _ W O R L D

Example: Adding Trigger Sequences

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

Trigger Sequence	Base64 Char.	Trigger Sequence	Base64 Char.
AAAD?Hp	9	AAAV?Hf	l
AAAD?Og	v	AAAf?Ft	p
AAAD?QI	7	AAAr?xj	V
AAAJ?MW	P	AAAx?Fj	1
AAAJ?PJ	F	AAAx?OC	n
AAAJ?VO	Z	AAAx?tx	5

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

- Example: Insertion of concatenation of trigger sequences `AAAD?HpAAAD?OgAAAD?QIAAAJ?MWAAAJ?PJAAAJ?VO` yields Kornblum's signature: `9v7PFZ`

Conclusion

Kornblum's Fuzzy Hashing

Security Aspects

Conclusion

Contact, Discussion

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

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)

Contact, Discussion

Thank you for your attention!

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