Differential Computation Analysis
Hiding your White-Box Designs is Not Enough

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Who is the attacker? External adversary, user, virus?
Where should we assume the attacker to be? What is realistic?

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Attacker “observes” data being transferred
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This is why you attend this conference!
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Adversary owns the device running the software.
Where is this used in practice?

Original use-case for white-box crypto is *digital right management*.

For example: streaming content, protecting DVD’s etc.
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How Host Card Emulation Works

![Diagram of Host Card Emulation](image)

**Recent trend**

Use *Host Card Emulation* (HCE) to communicate using *Near Field Communication* (NFC)
→ Replace the secure element with software.

Protection of the cryptographic key? How? **White-box implementation!**

*Source: Business Insider*
Huge demand for practical + secure white-box

- 2014: VISA + Mastercard support HCE
- [Berg Insight]: 86% of the Point of Sale devices in North America and 78% in Europe will support NFC by 2017.
- [IHS research]: By 2018, 2/3 of all shipped phones will support NFC.
- the protocols used need to use (and store!) AES / DES keys
  need for secure white-box cryptography.
Security of WB solutions - Theory

White box can be seen as a form of code obfuscation
- It is known that obfuscation of any program is impossible

Barak, Goldreich, Impagliazzo, Rudich, Sahai, Vadhan, Yang. On the (im)possibility of obfuscating programs. In CRYPTO 2001
- Unknown if a (sub)family of white-box functions can be obfuscated
- If secure WB solution exists then this is protected (by definition!) to all current and future side-channel and fault attacks!

Practice
- Only results known for symmetric crypto (all academic designs of standard crypto broken)
- Convert algorithms to sequence of LUTs
- Embed the secret key in the LUTs
- Obfuscate the LUTs by using encodings
Obfuscating the LUTs

\[(f_{0,i}, f_{1,i})A_i^{-1}a_{i,j}\]


Size of implementation: \(\approx 700\) kB
In practice the white box is the most essential but a **small part** of the entire software implementation

- Strong code obfuscation
- Binary is “glued” to the environment
  - Prevent code-lifting
- Support for traitor tracing
- Mechanism for frequent updating

More details see the invited talk at EC 2016 *Engineering Code Obfuscation* by Christian Collberg
Effort and expertise required

**Previous effort**

Previous WB attacks were **WB specific** which means knowing

- the *encodings*
- which *cipher operations* are implemented by
- which (network of) *lookup tables*

**Attack**

1. time-consuming reverse-engineering of the code
2. identify which WB scheme is used + target the correct LUTs
3. apply an algebraic attack
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Our approach
Assess the security of a WB implementation
✓ Automatically and very simply (see CHES challenge)
✓ Without knowledge of any implementation choices
  → only the algorithm itself
✓ Ignores all (attempts) at code-obfuscation
Tracing binaries

- Academic attacks are on open design
- In practice: what you get is a binary blob

Idea: collect information using using dynamic binary instrumentation tools (→ visual representation → use traces to find correlation)

- Record all instructions and memory accesses.

Examples of the tools we extended / modified
- Intel PIN (x86, x86-64, Linux, Windows, Wine/Linux)
- Valgrind (idem+ARM, Android)
Trace visualization

Based on Ptra, an unreleased Quarkslab tool presented at SSTIC 2014
Visual crypto identification: code
Visual crypto identification: code?
Visual crypto identification: code? data!

1 + 15

17.
Visual crypto identification: code? data?
Visual crypto identification: stack!
Differential Computation Analysis

Naïve approach: Port the white-box to a smartcard and measure power consumption
Differential Computation Analysis

**Naïve approach**: Port the white-box to a smartcard and measure power consumption

**Better approach**: each bit is equally important

→ Serialize bytes in a succession of bits
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Visual challenge: try to identify the rounds
(Hint: auto-correlation can reveal them!)
DCA: DPA on software traces

HW analogy: this is like probing each bus-line individually \textit{without any error}
WB implementations should not leak any side-channel information (by definition of the WB attack model): let’s check!

<table>
<thead>
<tr>
<th>WB implementation</th>
<th>Algorithm</th>
<th>#traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyseur challenge, 2007</td>
<td>DES (Chow+)</td>
<td>65</td>
</tr>
<tr>
<td>Hack.lu challenge, 2009</td>
<td>AES (Chow)</td>
<td>16 (no encodings)</td>
</tr>
<tr>
<td>SSTIC challenge, 2012</td>
<td>DES</td>
<td>16 (no encodings)</td>
</tr>
<tr>
<td>Klinec implementation, 2013</td>
<td>AES (Karroumi, dual ciphers)</td>
<td>2000 → 500</td>
</tr>
</tbody>
</table>

Intuition why this works:
Encodings do not sufficiently hide correlations when the correct key is used.

A lot of potential for follow-up work!

Use the extended research results from the grey box world

Countermeasures
- Use random masks / delays → white-box model allows to disable entropy source
- Use static random data within the white-box itself?
- Use ideas from threshold implementation? [TI]
- Better DBI framework detection mechanisms
- DCA might fail when using large encodings → larger LUTs → algebraic attacks still work


Other attacks
Riscure has proven software fault attacks (DFA) work too [RISCURE].
Once there are countermeasures against DCA and DFA, can we use any of the other known advanced SCA in this setting?

https://github.com/SideChannelMarvels

Any help to complete our collection of open whitebox challenges and attacks or to improve our tools is highly appreciated!
Conclusions

• Software-only solutions are becoming more popular
  • white-box crypto

• Traditional (DRM) and new use-cases HCE (payment, transit, …)

• Level of security / maturity of many (all?) WB schemes is questionable
  • Open problem to construct asymmetric WB crypto
  • Industry keeps design secret

• DCA is an automated attack which can be carried out without any expertise
  • Counterpart of the DPA from the crypto HW community

• This hopefully sparkles more interest in both cryptographic and cryptanalytic white-box research!
SECURE CONNECTIONS FOR A SMARTER WORLD