THE (NOT SO PROFITABLE) PATH TOWARDS AUTOMATED HEAP EXPLOITATION

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2018-10-16 | HackLu 2018 | Luxembourg, LU

DISCLAIMER

This research was accomplished by me in my personal capacity during my spare time.

DON'T BE TOO JUDGEMENTAL PLEASE! :)

full disclosure: I am NOT a vulnerability researcher!

ABOUT ME

```
echo 'Stare at binaries during the day';

echo 'Blackhoodie - Core Organizer and Board Member';
echo 'HackLu`s program`s committee';
echo 'Disobey`s Lead of Technical Content';
echo 'x86 Assembly & RE101 - Lead of both groups @chaosdorf';
echo 'Logical Programming, RE, static analysis, Mountaineering FTW';
echo 'Wannabe "Karaoke" singer';

echo 'Stare at binaries by night';
```

BlackHoodie

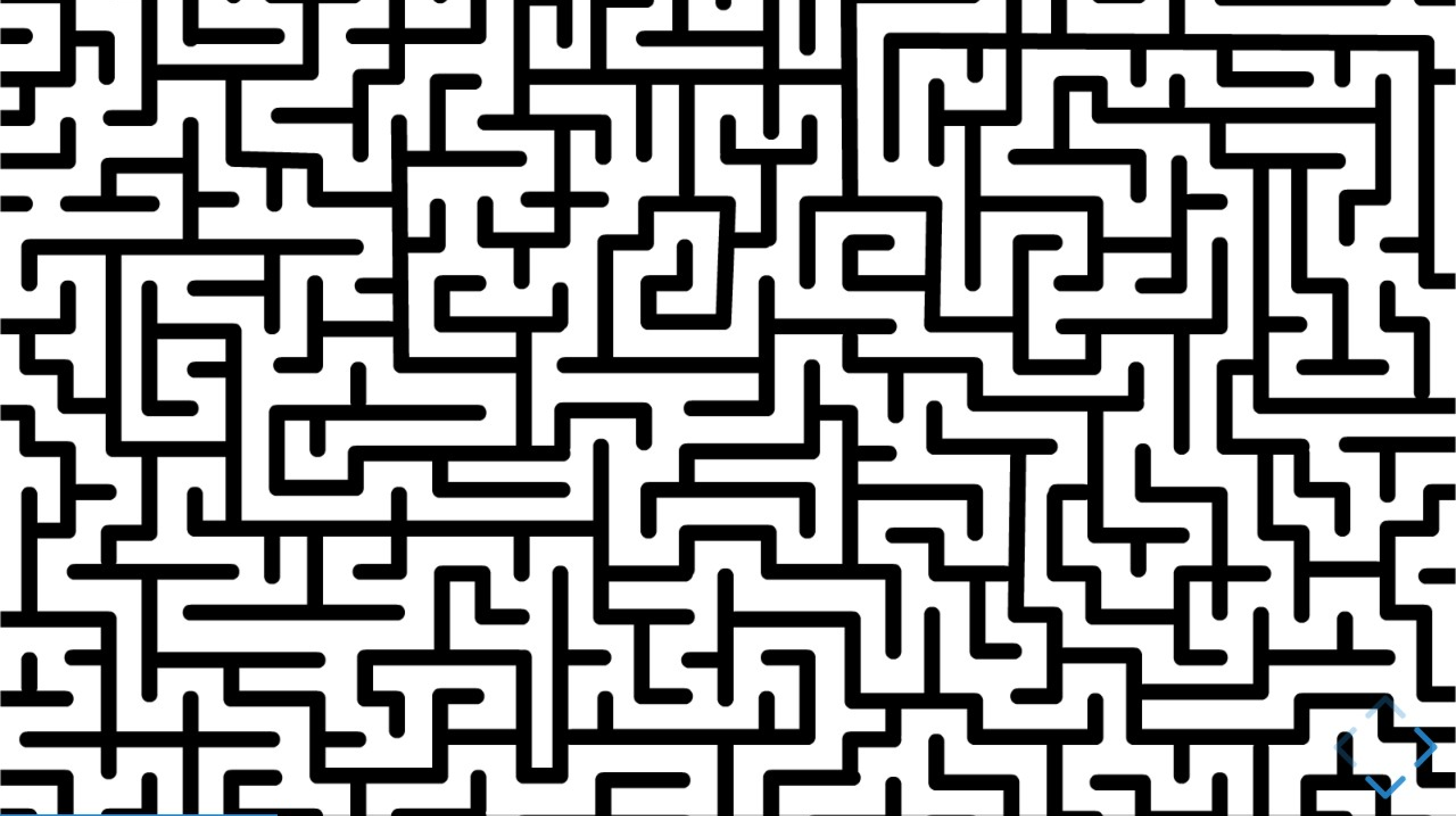
WHAT AM I GOING TO TALK ABOUT?

- constraint logic programming (CLP)
- solvers
- static analysis scalability
- the memory
- oh yeah, heaps...

S..A..T.. WHAT?

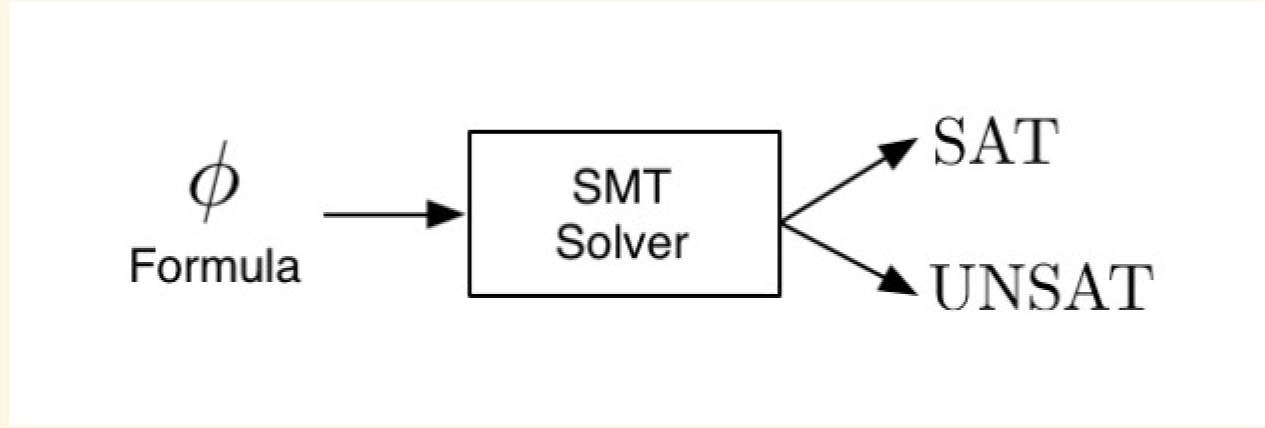
- Solver!
- Satisfiability Modulo Theories (SMT)

CONSTRAINTS



"Constraint programming represents one of the closest approaches computer science has yet made to the Holy Grail of programming: the user states the problem, the computer solves it." Eugene C. Freuder, Constraints, April 1997

AUTOMATED THEOREM PROVING



- Hardware and Software → Large-scale verification
- Languages specification and Computing proof obligations

SYMBOLIC EXECUTION

IT LOOKS LIKE THAT ...

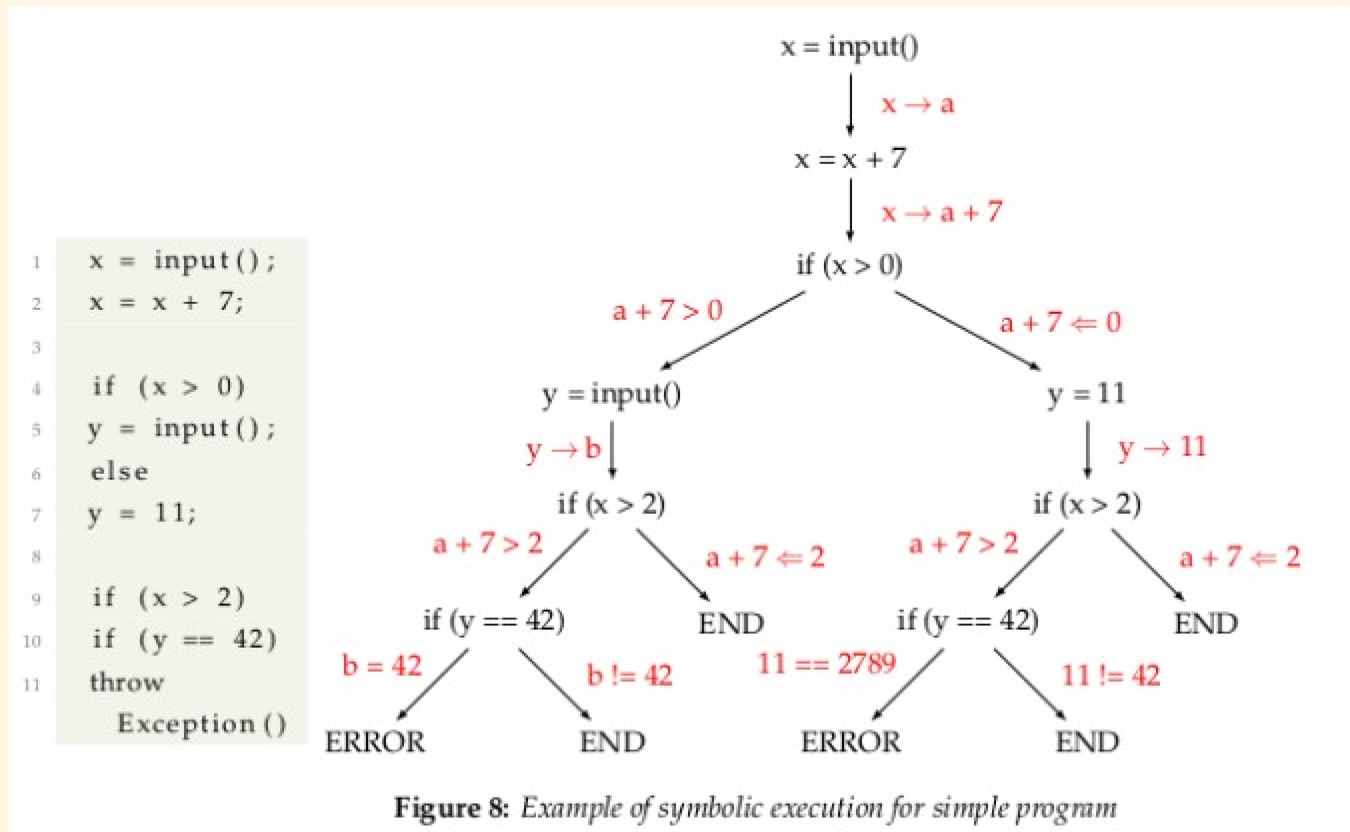
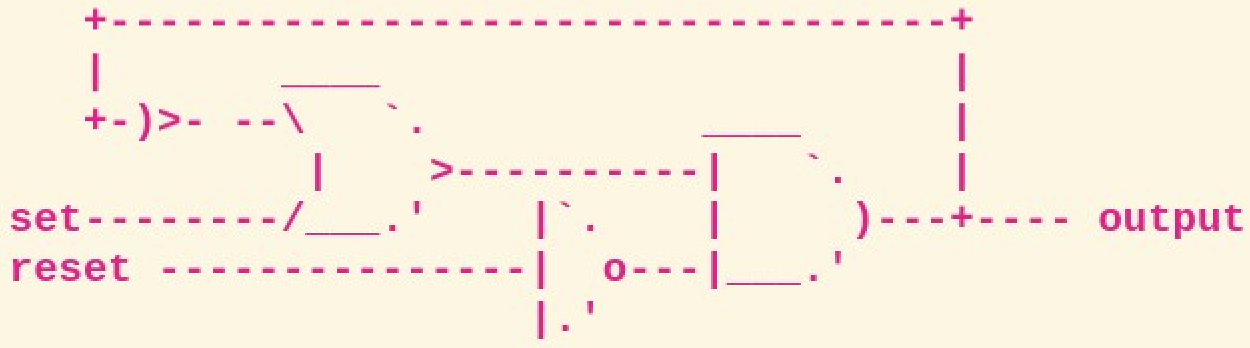


Figure 8: *Example of symbolic execution for simple program*

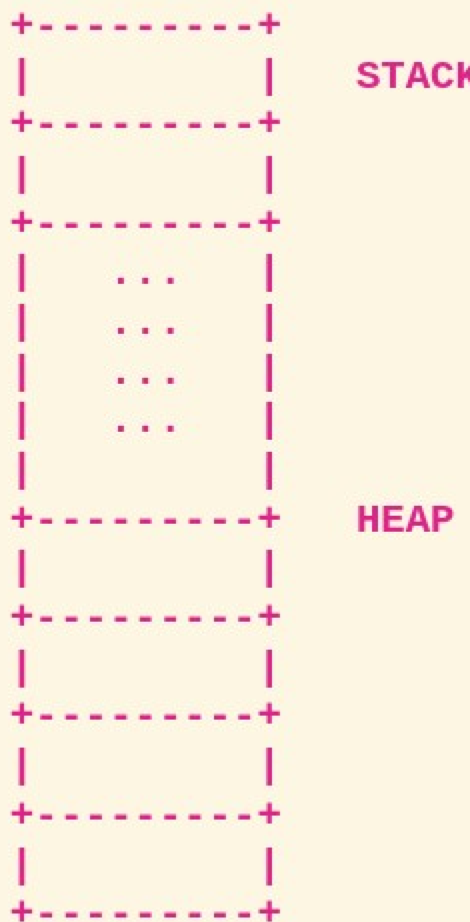
HOW IT WORKS

- Create a process (pc = 0, state = [])
- Add the process (pc, state) to the domain system D
- while D not empty:
  - Remove process (pc, state) from system
  - Execute it until the next branching point
    - If both paths are feasible, add both to D
    - if just one is feasible, add the feasible path and the negation of the not feasible path to D

THE LOGIC GATES OF THE MEMORY



50 SHADES OF MEMORY



the IMPLEMENTATION

A HEAP OF INFORMATION

APPLICATIONS

MALWARE ANALYSIS

- Obfuscation
- Compiler optimizations
- Crypto-analysis

BUG HUNTING

- Fuzzing
- Code verification
- Binary Analysis

EXPLOITATION

- PoC (Proof of Concept)
- AEG (Automated Exploit Generation)
- APG (Automated Payload Generation)

WHAT WE ARE LOOKING FOR

- Vulnerable

WHAT WE ARE LOOKING FOR

- Vulnerable ***AND Exploitable***

HOW TO CRASH !

AUTOMATION OUT THERE

- Exploratory testing
- Dynamic taint analysis
- Abstract interpretation

AUTOMATION OUT THERE

- Klee
  - Open source symbolic executor
  - Runs on top of LLVM
- Manticore
  - Symbolic execution
  - Taint analysis
  - Binary instrumentation

TOOL OF CHOICE

FORWARD

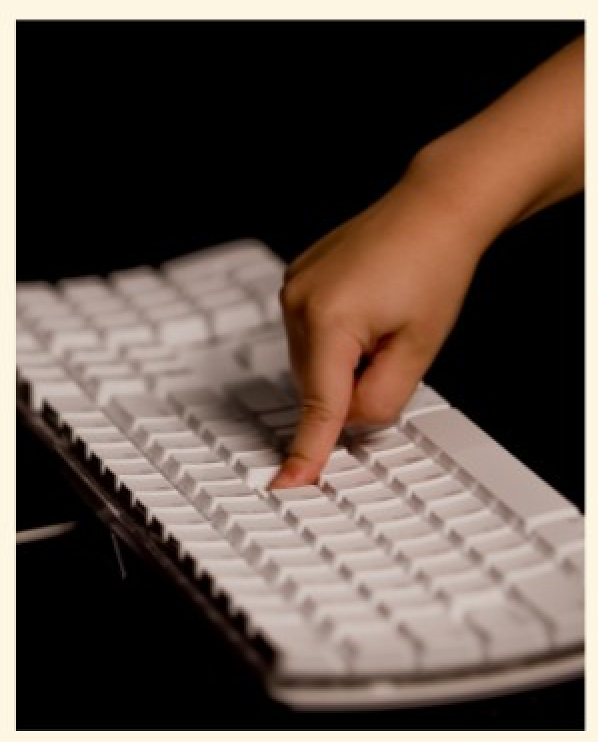
SYMBOLIC

EXPLOIT GENERATION

Find a bug — easy right?

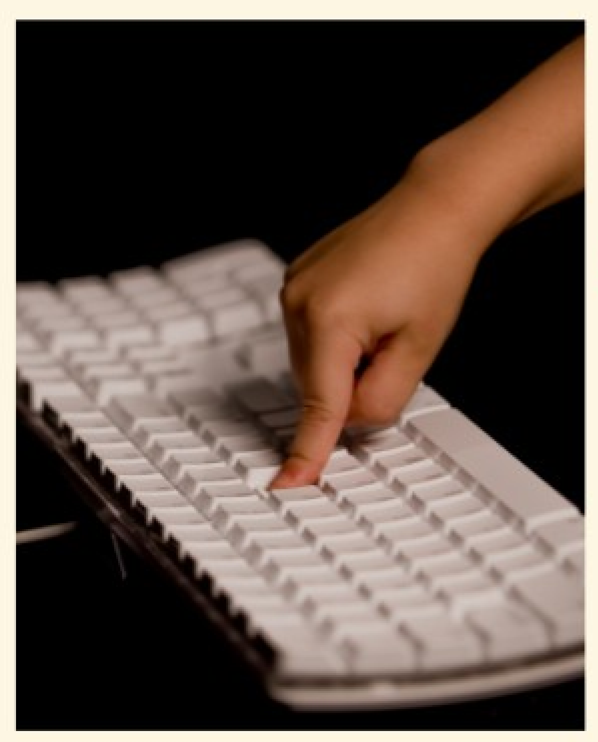
Def: Vulnerable Path for input ε is Π_(vulnerability)(ε)

PLAN



Theorem: Given a program, automatically find vulnerabilities and generate exploits for them.

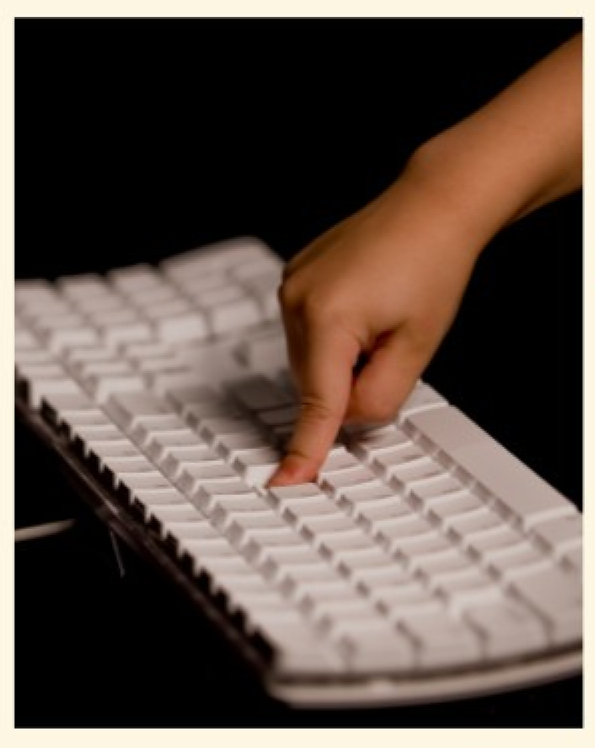
PLAN



Theorem: Given a program, automatically find vulnerabilities and generate exploits for them.

- direct influence

PLAN



Theorem: Given a program, automatically find vulnerabilities and generate exploits for them.

- indirect influence

```
malloc(strlen(user_input));
```

EXPLOIT GENERATION

Check if it is exploitable

Not that easy anymore...

$\Pi(vulnerability)(\varepsilon) \land \Pi(exploit)(\varepsilon) = true$

Where Π_(exploit)(ε) is the attacker's logic

EXPLOIT GENERATION

Implement Π_(exploit)(ε)

for a really special case Π*(vulnerability)(ε) ∧*
Π(exploit)(ε)

and then it works MOST of the times

is it really automated then?

EXPLOIT GENERATION

EXTRA: Evaluate

- Find the HEAP
- Exploit Verification
- State Space Explosion
- Environment Definition

LIMITATIONS

THEORETICAL #1

Rice's Theorem

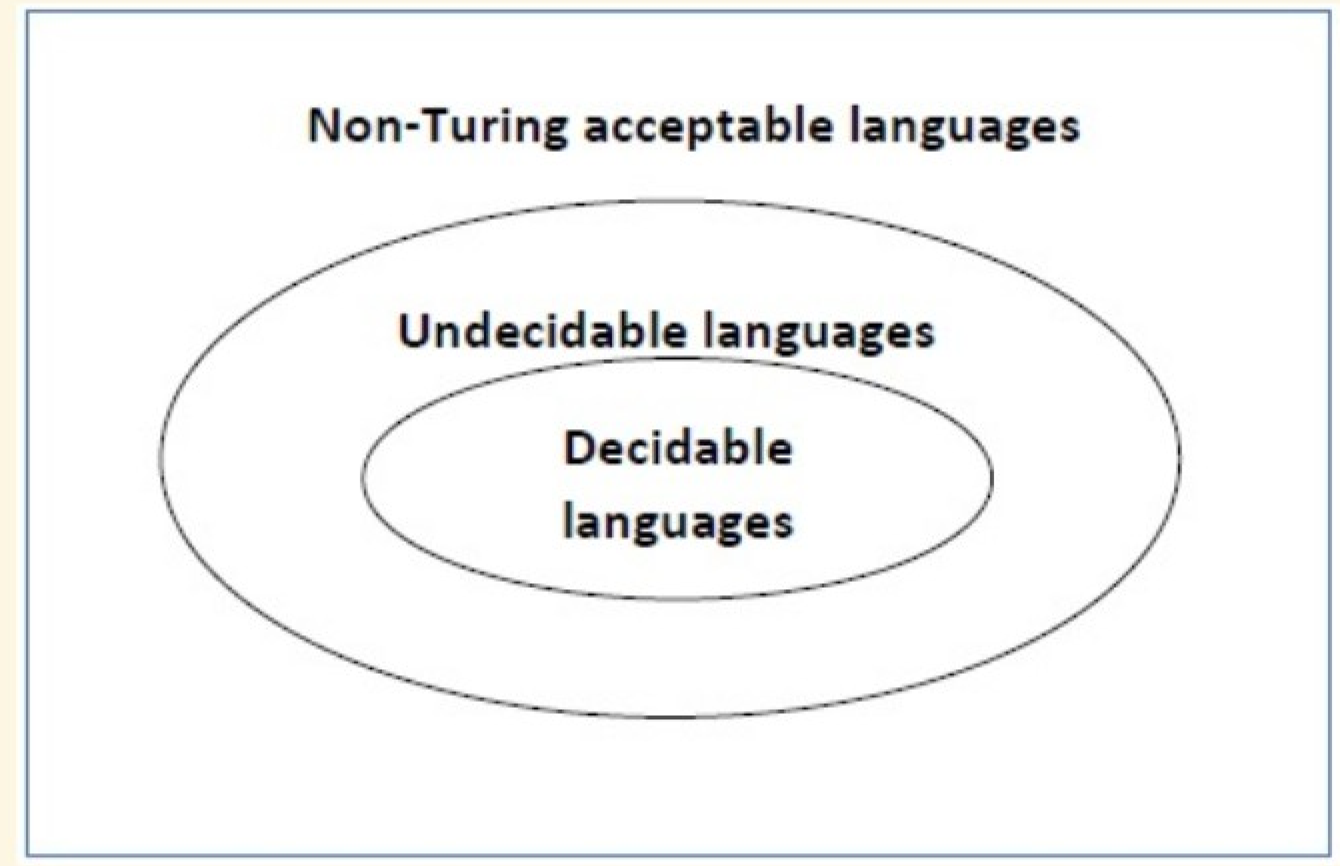
Theorem

Let L be a subset of strings representing Turing machines, where

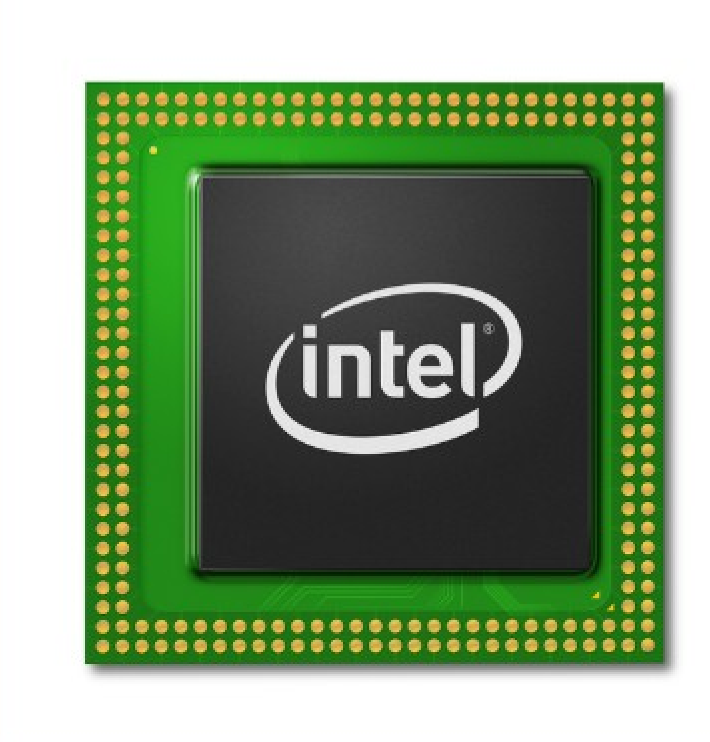
1. If M_1 and M_2 recognize the same language, then either $\langle M_1 \rangle, \langle M_2 \rangle \in L$ or $\langle M_1 \rangle, \langle M_2 \rangle \notin L$.
2. $\exists\, M_1, M_2$ s.t $\langle M_1 \rangle \in L$ and $\langle M_2 \rangle \notin L$.

Then L is undecidable.

THEORETICAL #2



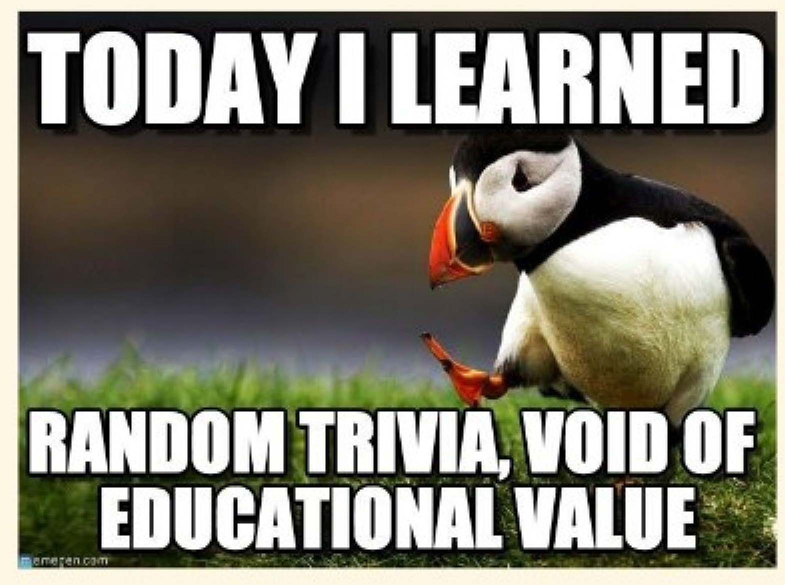
PRACTICAL



Remember...

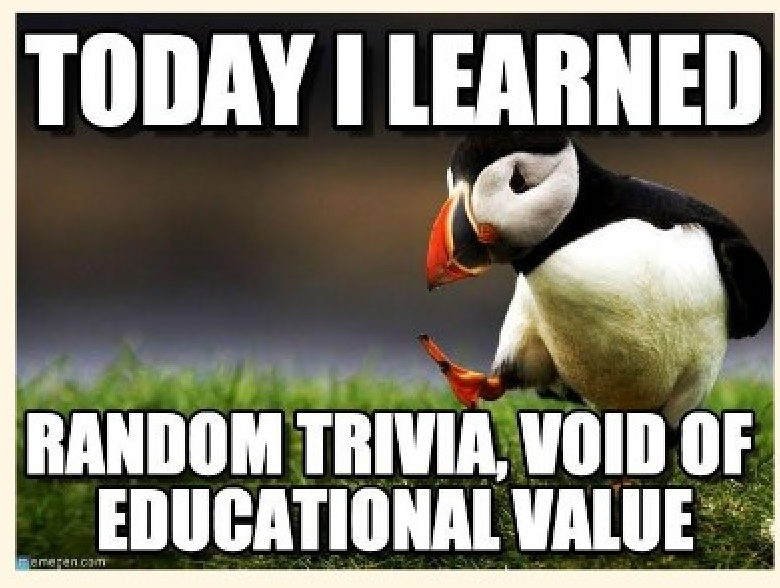
CONCLUSION

LEARNINGS / TAKE AWAY



- Symbolic execution is a powerful tool ~~while analysing malware~~ for vulnerability research
- SMT solvers can reason and generate exploits

LEARNINGS / TAKE AWAY



- Symbolic execution can be ~~is~~ a powerful tool for vulnerability research
- SMT solvers can reason and generate exploits

WORK DONE:

- a binary garbage-code eliminator, a XOR search, some "cryptographic" algorithm breaker, a generic unpacker, a binary structure recognizer, a C++ class hierarchy reconstructor.

WORKING ON ...

- specialized constraint inference assistant for computer security problems

ACKNOWLEDGMENTS

- Sean Heelan
  - Automated Heap Layout Manipulation for Exploitation (Heelan et al. to appear in Usenix Security 2018)
  - and his time;
  - and inspiration!
- Marion Marschalek
- Heap Models for Exploit Systems (Vanegue, Langsec 2015)
- and the Intel Documentation I think ... ?

QUESTIONS?

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