Moka

Research Report

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devastating capability, revolutionary advantage

- Security Researcher at Assured Information Security

- Interests
  - Computation/Language Theory
  - Transmission mediums
- Long, bounded walks on the beach

Overview

- History of Moka
- Objective
- Experiment
- Results
- Summary

If at any point you have a question, please feel free to ask.

Crema

- **Research effort preceding Moka**
  - Demonstrated feasibility of use and security benefits of sub-TC programming languages
  - Calculated the effect of restricted computation on formal methods

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Moka

- **Quantify the effectiveness of applying LangSec principles to real life code**
  - Large data set
  - Builds off work done with Crema
- **Quantify:**
  - code termination (sub turing complete (**sub-TC**))
  - non-halting code (absolutely turing complete (**TC**))

Why do we care?

- **Turing Complete Execution**
  - Code will accept arbitrary inputs
  - These inputs control execution behavior
  - An input crafted by an attacker, can lead the system into an untrustworthy state. (The land of Weird Machines)

Why do we care? II

devastating capability, revolutionary advantage

- **Sub-TC Execution:**
  - Input languages are restricted and well-defined
  - Program execution is determinate and can be proven safe (from a LangSec perspective.)
  - Cannot be applied to all applications.

    Eg. Input handling

A Case for LangSec

- **LangSec oriented coding is not only feasible to use in day to day coding, it is downright foolish NOT to program with it in mind!**
  - How much utility does it have in large programs
  - Difficulty of implementation
  - Identification of refactorable areas
- **Think:** We should be pushing for the 5th stage of acceptance, as per Dan Geer*

http://spw15.langsec.org/geer.langsec.21v15.txt

Tools and Data

- LLVM/Clang-3.8
- Linux Kernel 4
- Python 2.7

LLVM

- **LLVM**
  - Modular and abstracted open-source compilation tool-chain
  - Compiles to immediate representation (IR) for advanced optimization and static analysis/symbolic execution
  - Highly extensible passes, allowing development of custom interpretation and modification of compilation units

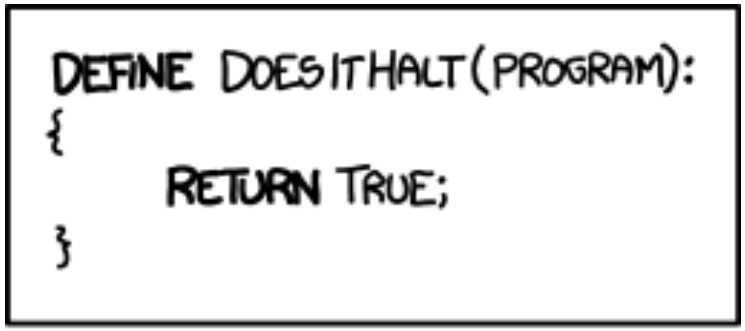
Goals

- **Create a series of diagnostic tools to gather relevant data***
  - Input language
  - SLOC (Source Lines of Code)
  - Minimum machine power classification

  * the halting problem is a harsh mistress. Some manual analysis required!

Goals II

- **Use LLVM passes to modify code**
  - Is the code able to be expressed in a sub-TC after modifications?



THE BIG PICTURE SOLUTION
TO THE HALTING PROBLEM

Technical Approach

- **Loops**
  - Loops with a defined bound for their induction variable and no other internal variable modifiers terminate
  - What about more ambiguous bounds?

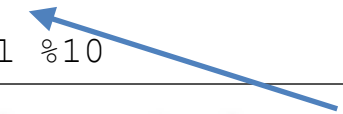
- **Recursion***
  - If we can unwind with LLVM then it counts as sub-TC, otherwise manually analyze or count as TC to be safe

* Not really a factor here, as we'll see later…

Pass Example


```
for (i = 0 ; i < 10 ; i++)
```

```
; <label>:3                                     ; preds = %7, %0
  %4 = load i32, i32* %i, align 4
  %5 = icmp slt i32 %4, 10
  br i1 %5, label %6, label %10
```



induction variable is defined and known to have an upper bound.

Internal induction variable modifications are simplified with llvm alias analysis

What about something a little more complicated?

Pass Example II


```
int buff[5] = {0,1,2,3,4};
for (i = 0 ; i < buff[2] ; i++)
```

```
; <label>:3                                          ; preds = %9, %0
  %4 = load i32, i32* %i, align 4
  %5 = getelementptr inbounds [5 x i32], [5 x i32]* %buff, i64 0, i64 2
  %6 = load i32, i32* %5, align 8
  %7 = icmp slt i32 %4, %6
  br i1 %7, label %8, label %12
```

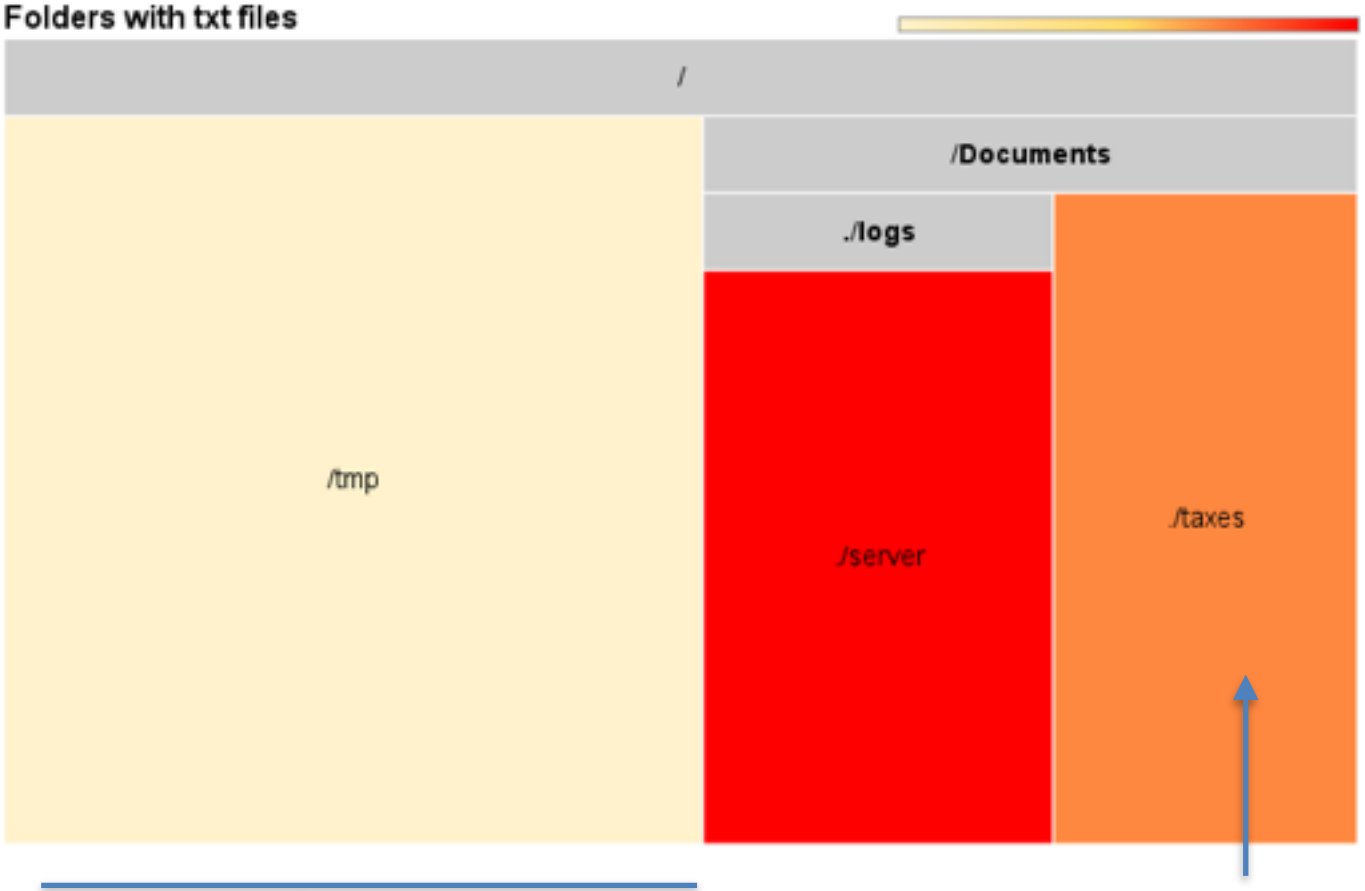
No Argument Promotion!

After promotion pass:

```
%4 = load i32, i32* %i, align 4
%5 = getelementptr inbounds [5 x i32], [5 x i32]* %buff, i64 0, i64 2
%6 = load i32, i32 * %4, align 8
; <label>:3                                          ; preds = %9, %0
  %7 = load i32, i32* %5, align 8
  %8 = icmp slt i32 %4, %6
  br i1 %8, label %9, label %12
```

Argument promoted!

Graphs are Hard!

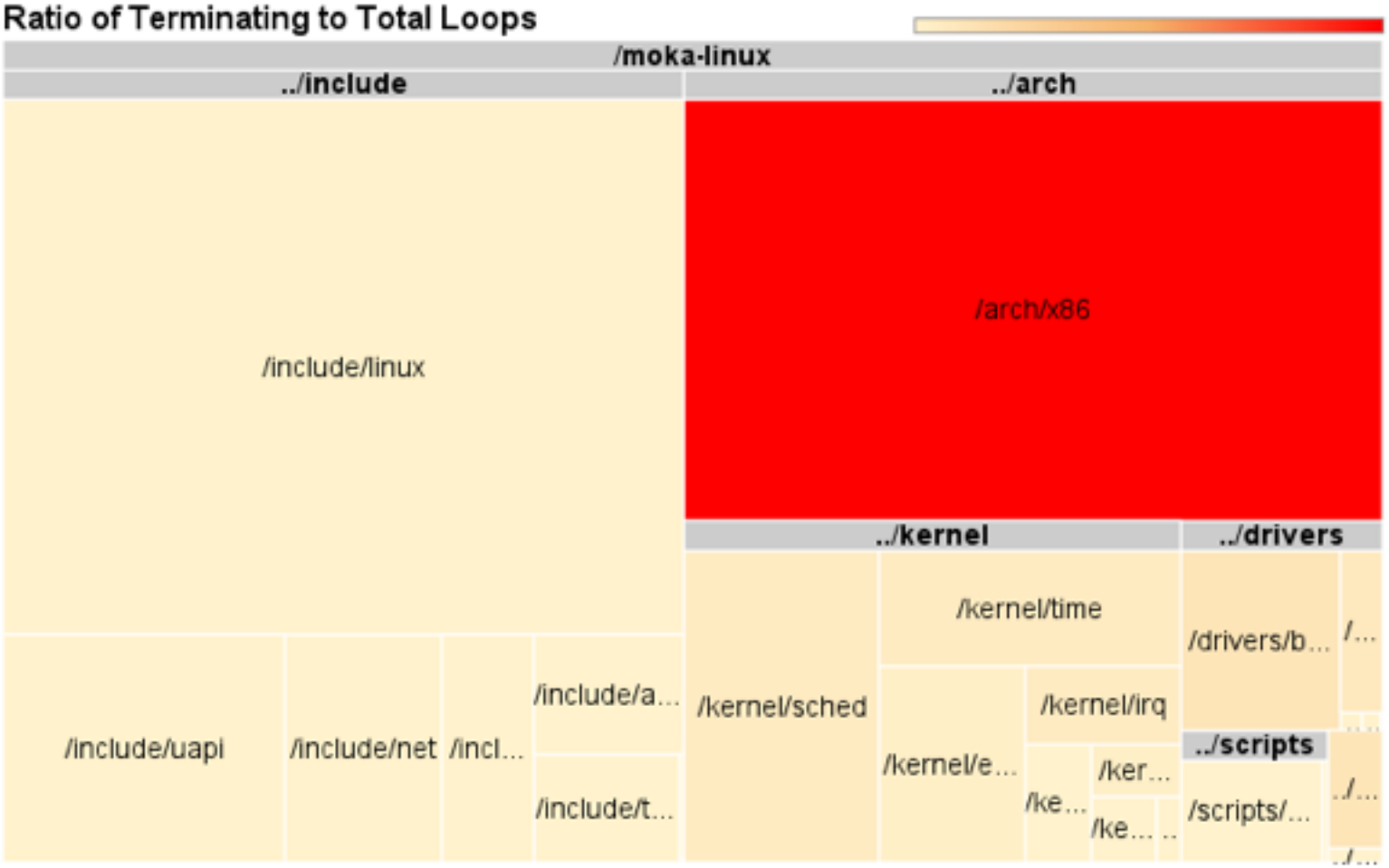



```
/
  /tmp
    foo.json
    passwords.pdf
    … (no txt)
  /Documents
    /taxes
      SSID.jpg
      expenses.txt
    /logs
      /server
        23986129.txt
        10298182.txt
        … (lots more txt)
```

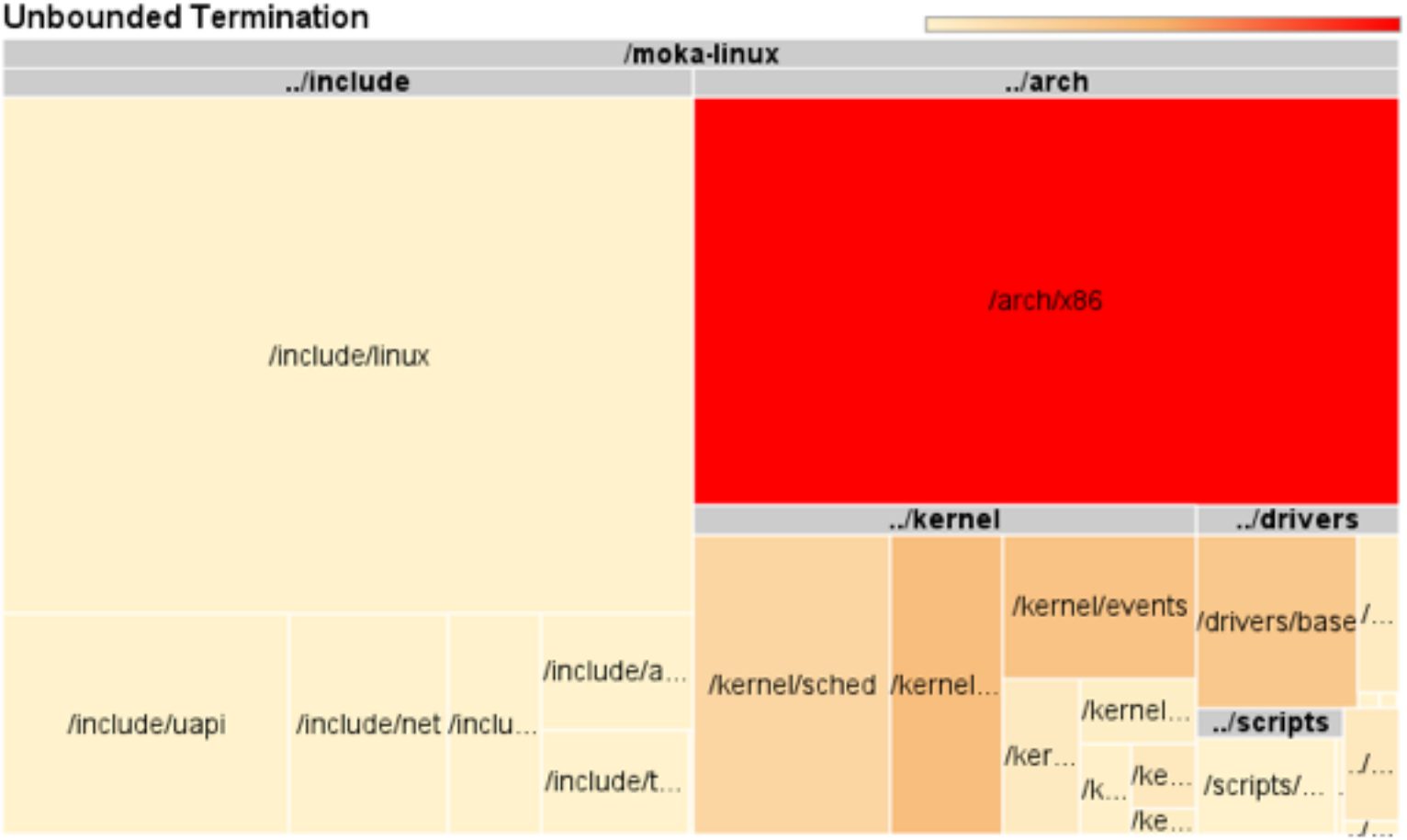
Area of Rectangle will ALWAYS be Source Lines Of Code (SLOC)

Saturation is concentration with respect to graph title

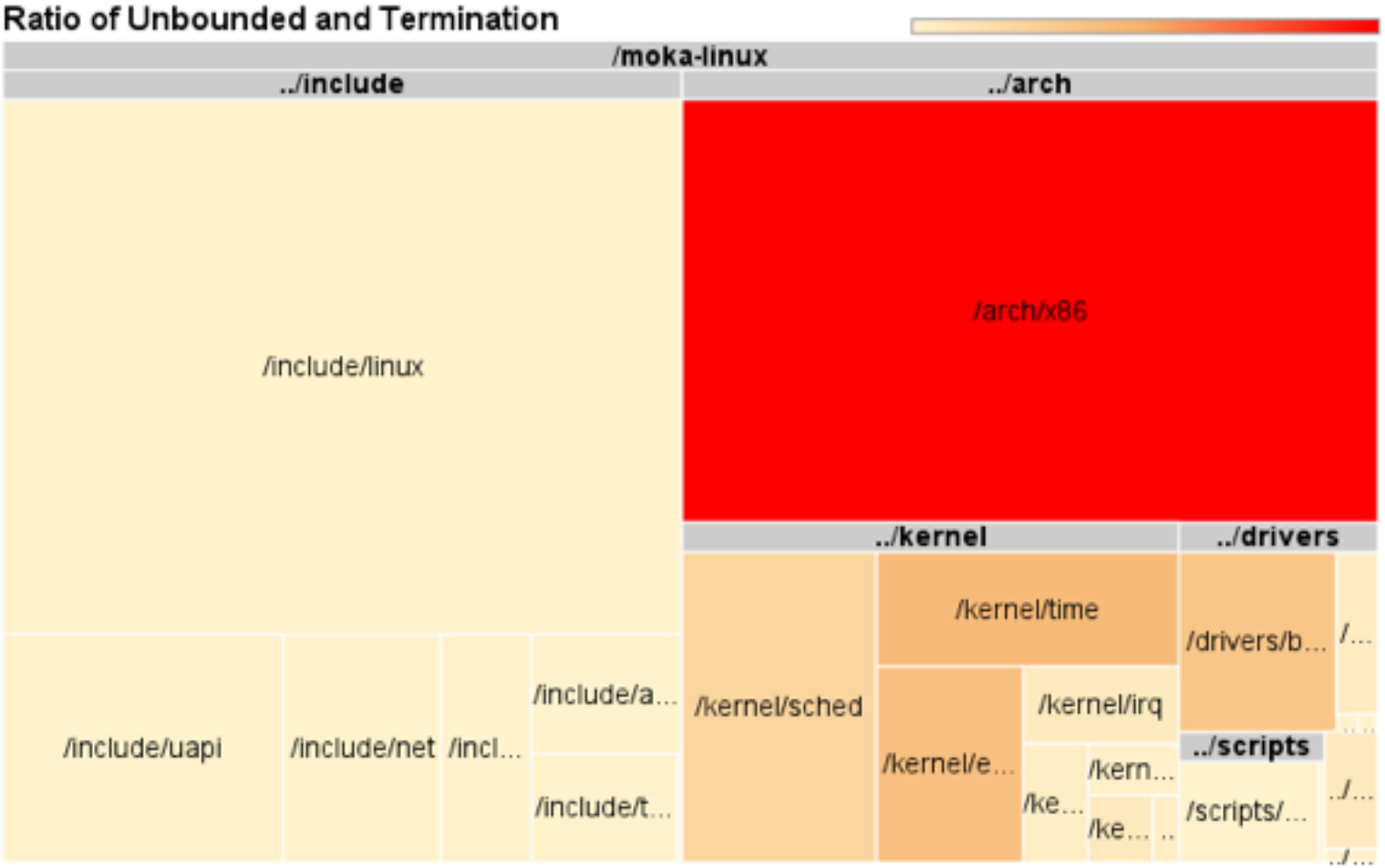
Sub-TC


Ratio of Terminating to Total Loops
/moka-linux
../include
../arch
/include/linux
/arch/x86
../kernel
../drivers
/kernel/time
/drivers/b...
/...
/include/uapi
/include/net
/incl...
/include/a...
/include/t...
/kernel/sched
/kernel/e...
/kernel/irq
/ke...
/ker...
/ke...
../scripts
/scripts/...
../...
../...

Unknown (So Far)



Sub-TC Potential



Results So Far

SLOC	354337
% ANSI C	~96%
Number of Loops	2473
Terminating Loops	305
Undecided (need evaluation)	2168
Functions w/ Undecided Loops Vs Total Functions (%)	23%

Summary / Follow-up

- **Much of the linux kernel already can be run sub-TC**
- **It is possible to determine if loops can be run sub-TC or modify them to run with lower computational power**
- **Look at a different domain (Eg. Application Servers)**
  - More recursive calls
  - Less refinement than kernel

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Questions/Discussion

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