# Meta-level Compilation

Presentation by Tony Ling

# What Is This Presentation About?

- A problem in software systems
- Common solutions and their inefficiencies
- Introduction meta-level compilation and examples

# What is the problem?

**Software systems have rules they must be obeyed**

**Examples of System Rules:**

- **Variable A must be protected by lock B before being accessed**
- **Message handlers should be free buffers ASAP**
- **Interrupts must be enabled after being disabled**
- **Shared variables not modified should be protected with read locks**

# Common Methods of Rule Violations Testing

- Formal Verification
- Test Cases
- Manual Inspection

# Formal Verification

**Using theorem provers or model checkers by building abstract formal specification**

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**Some Problems:**

- **Cost Effectiveness**
- **Specifications are not easy to build**
- **What about agile software development?**

# Test Cases

**Creating test cases to test for rules dynamically**

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**Issues:**

- **Time consuming**
- **Narrowing down the cause of bug**
- **Practicality**

# Manual Inspection

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**Problems:**

- **Large code base**
- **Humans, can’t trust them**

# Rule Template

**System rules follow certain templates:**

- **Never/always do X**
- **Do X rather than Y**
- **Always do X before/after Y**
- **Never do X before/after Y**
- **In situation X, do/not do Y**
- **In situation X, do Y rather than Z**

# Rule Template

- Never/always do X
- Do X rather than Y
- Always do X before/after Y
- Never do X before/after Y

- In situation X, do/not do Y
- In situation X, do Y rather

- Enable interrupts after disabling them
- Never read before obtaining lock
- If a shared variable is not modified, protect with read lock

# Static Compiler Analysis

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**Problem:**

- **Compilers ignorant of the ‘meta’ semantics of the software system**

# Meta-level Compilation

- **Allow developers to extend compilers with system specific checkers**
- **Compiler extensions are written in a high level state-machine language called *metal***
- **These extensions check for specific system rules**

# How does it work?

- A *metal* extensions is a collection of state machines
- Syntax pattern matching triggers state transitions
- Patterns are written in an extended version of the base language
- Extensions can run in either flow insensitive or flow sensitive modes
- Extensions goes through all flow paths of source code while keep tracking states

# Example 1

```
sm check_interrupts{
    decl {unsigned} any_flag;

    pat enable = { sti(); }
               | { restore_flags(any_flag);};
    pat disable = { cli(); };

    is_enabled: disabled ==> is_disabled
              | enable ==> { err(“double enable”); };
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               | $end_of_path$ ⇒ { err(“exiting w/intr disabled!”); };
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$end_of_oath$ ==> error

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Variable 'flag' matches 'any_flags' since it is of type unsigned

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1: state decl any_pointer v;
2:
3: start: { kfree(v) } ==> v.freed;
4:
5: v.freed: { *v } ==> v.stop,
6:     { err(“using %s after free!”, mc_identifier(v)); }
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v.stop is a special state that means that the instance of v is no longer tracked

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6:      kfree(w);
7:      q = p;
8:      p = 0;
9:   }
10:  if(!x)
11:     return *w;
12:  return *q;
13:}
14:int contrived_caller(int *w, int x, int *p {
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start at contrived_caller

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x = true

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17:  return *w;
18:}
```

v:p-> freed
v:w-> freed

x = true

**Hallem, Seth et al. *A system and language for building system-specific, static analyses*. ACM, 2002.**

# Example 2

```
1: state decl any_pointer v;
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3: start: { kfree(v) } ==> v.freed;
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```

v:p-> freed
v:w-> freed
v:q-> freed

x = true

instance of v created due to assignment

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x = true

v:w-> freed
v:q-> freed

v:p goes to stop state and removed

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x = true

v:w-> freed

v:q goes to stop state and is removed

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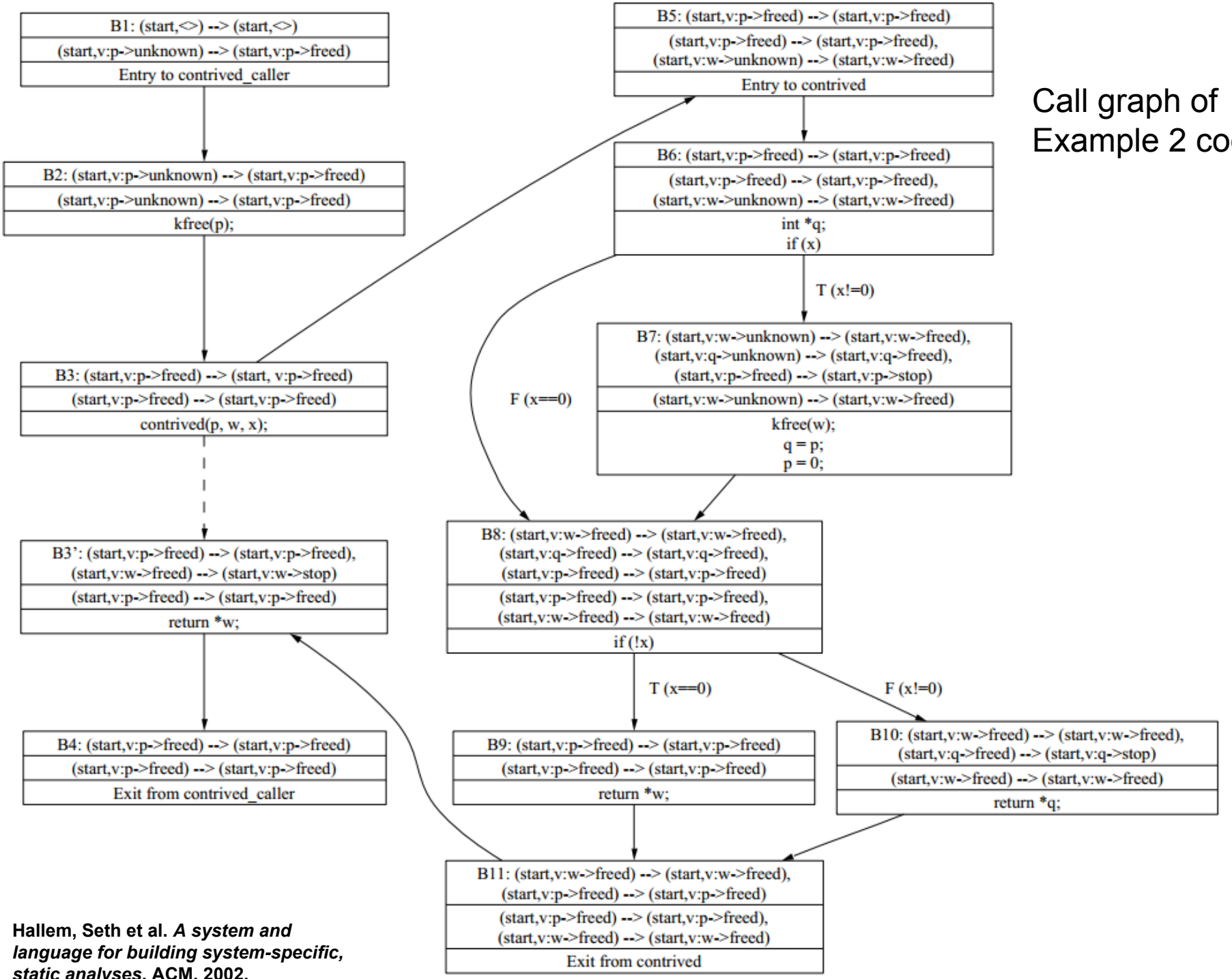
v:p-> freed
v:q-> freed

contrived returns with
v:p and v:w

**Hallem, Seth et al. *A system and language for building system-specific, static analyses*. ACM, 2002.**




Call graph of Example 2 code

**Hallem, Seth et al. *A system and language for building system-specific, static analyses*. ACM, 2002.**

# Some Problems with MC

**Extensions are not verifiers**

**False positive and false negatives occur**

**Underlying state machine**

# Coverity

**Coverity founded by Dawson Engler, Seth Hallem, Andy Chou, Benjamin Chelf in 2002**

**According to Crunchbase as of 10/20/2014:**

- **Received $22 million in round of investment in 2008**
- **Acquired by Synopsys for $350 million in February 19, 2014**

# References


Engler, Dawson et al. "Checking system rules using system-specific, programmer-written compiler extensions." *Proceedings of the 4th conference on Symposium on Operating System Design & Implementation-Volume 4* 22 Oct. 2000: 1-1.

Hallem, Seth et al. *A system and language for building system-specific, static analyses*. ACM, 2002.

http://www.crunchbase.com/organization/coverity