Automatic OS Kernel TCB Reduction by Leveraging Compile-Time Configurability

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supported by DFG and TClouds

System Software is Configurable

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- Complexity increases considerably
- How to find the best configuration?

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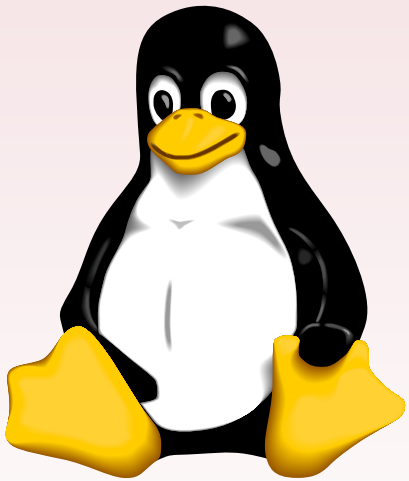

Linux v3.2 contains:

11.800 features

1.700 build-system files

18.300 source-code files

89.000 `#ifdef` blocks

How much functionality does Linux come with?

- Configuring Linux is a hard task
  - The Linux kernel contains ample functionality:
    - 24 Architectures (x86, arm, powerpc, ...)
    - Drivers
    - (Default) scheduling strategies
    - Optional security features
    - You name it!
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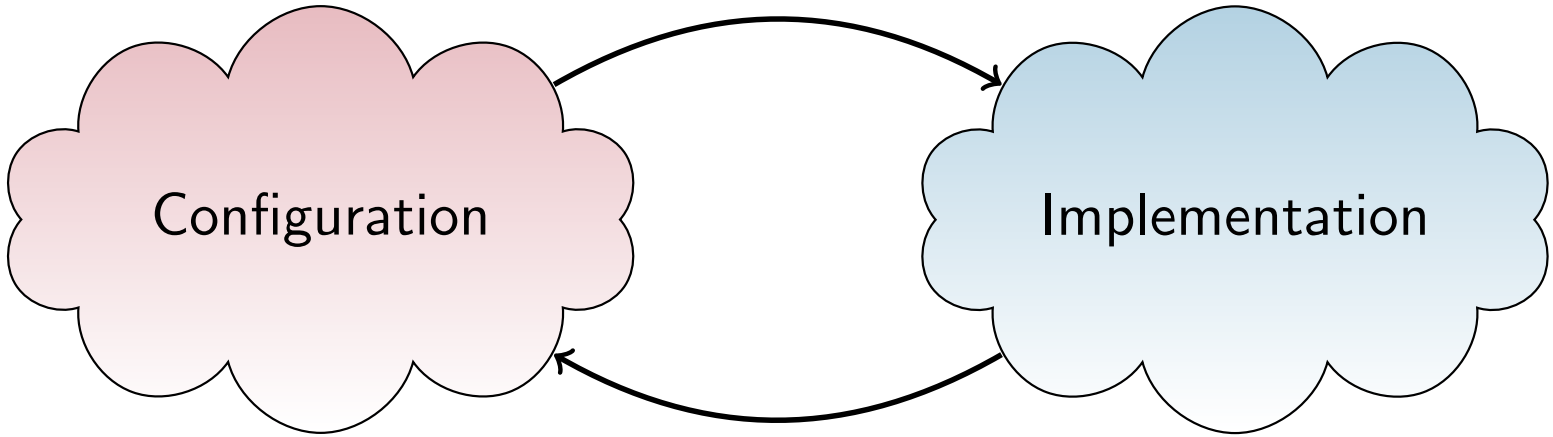
- Configuration options, may appear or disappear with every new Linux kernel release
- Distribution kernels mostly do work
  - Distros invest an enormous amount of manpower to keep up
  - Make little assumptions on hardware and use case

A Closer Look at the State of the Art



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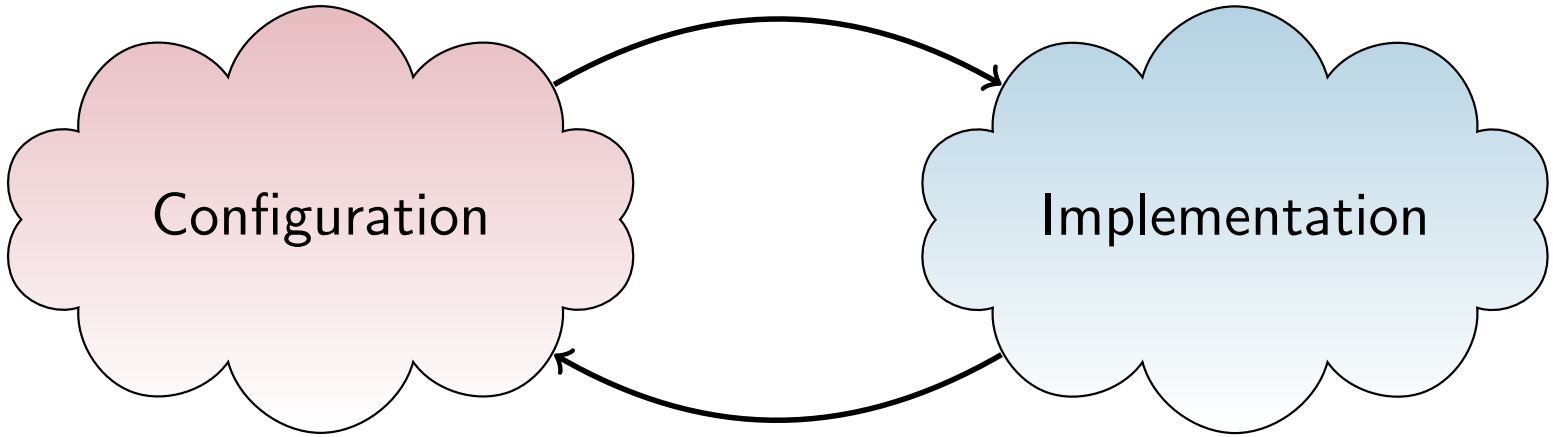
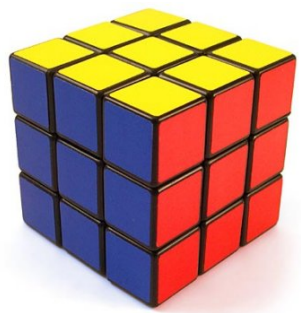


Single Configuration provided by the Distributor

Complex Implementation of Variability

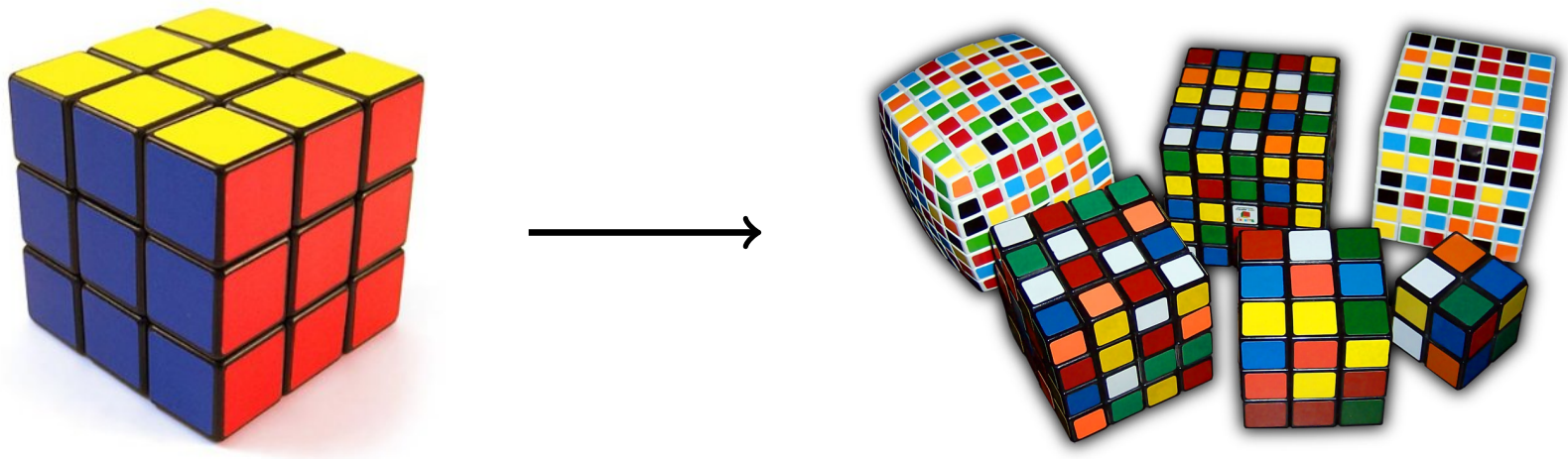


KCONFIG

`#ifdef`-Hell
Convoluted `make` files
etc.

The Problem

- Without a given use-case, the distribution kernel has to include all available functionality
- As side-effect, this maximizes the attack surface!
- Each use-case needs its specific, ideal configuration



Idea: Automated Tailoring of the Linux Configuration

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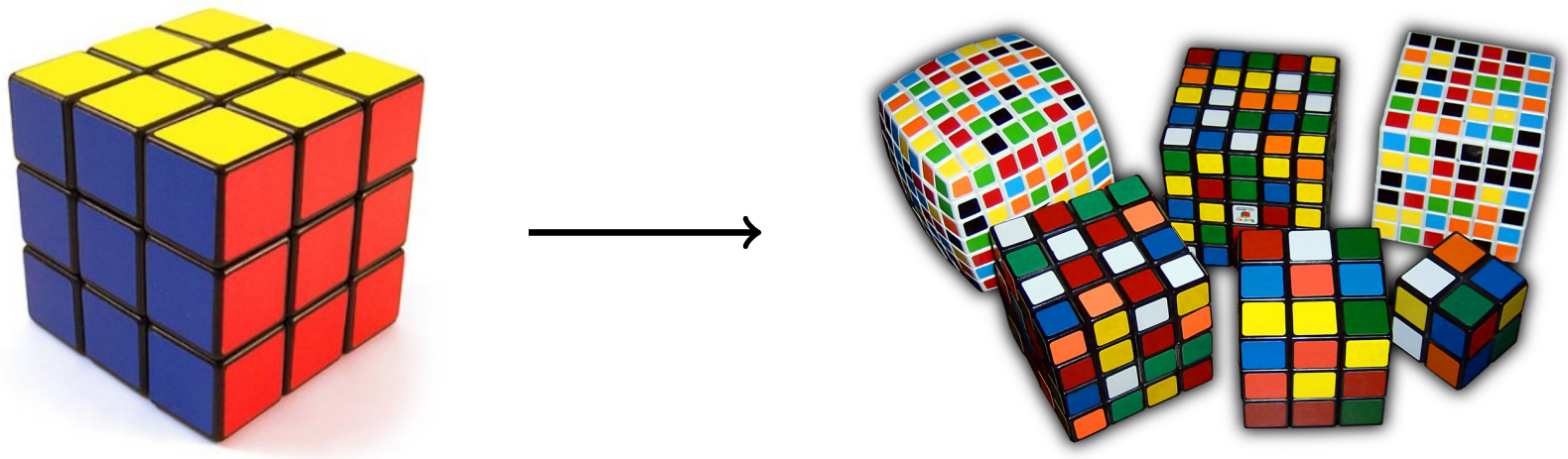
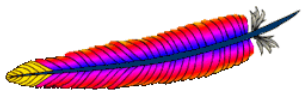


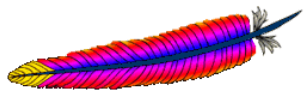
→ Automatically derive an ideal configuration for a given use case.

Approach at a glance



Specific
Scenario

Approach at a glance

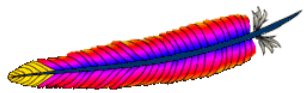


Specific Scenario

CONFIG_X86=y
CONFIG_SCSI=n
[. . .]

Tailored Configuration

Approach at a glance



Specific Scenario

automatically derive

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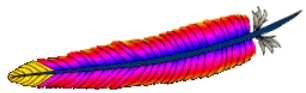
Tailored Configuration

observe

FTRACE

Approach at a glance



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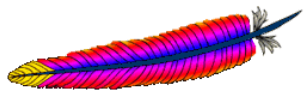
Tailored Configuration

debug symbols

```
0x8043566 — kern/sched.c:80
0x80452d8 — drivers/scsi.c:4302
[...5000 more locations]
```

Identify in Source Code

Approach at a glance



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Identify in Source Code

establish

φ

Holistic Variability Model

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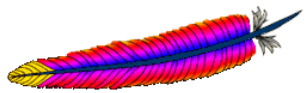

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Tailored Configuration

employ SAT checker

φ

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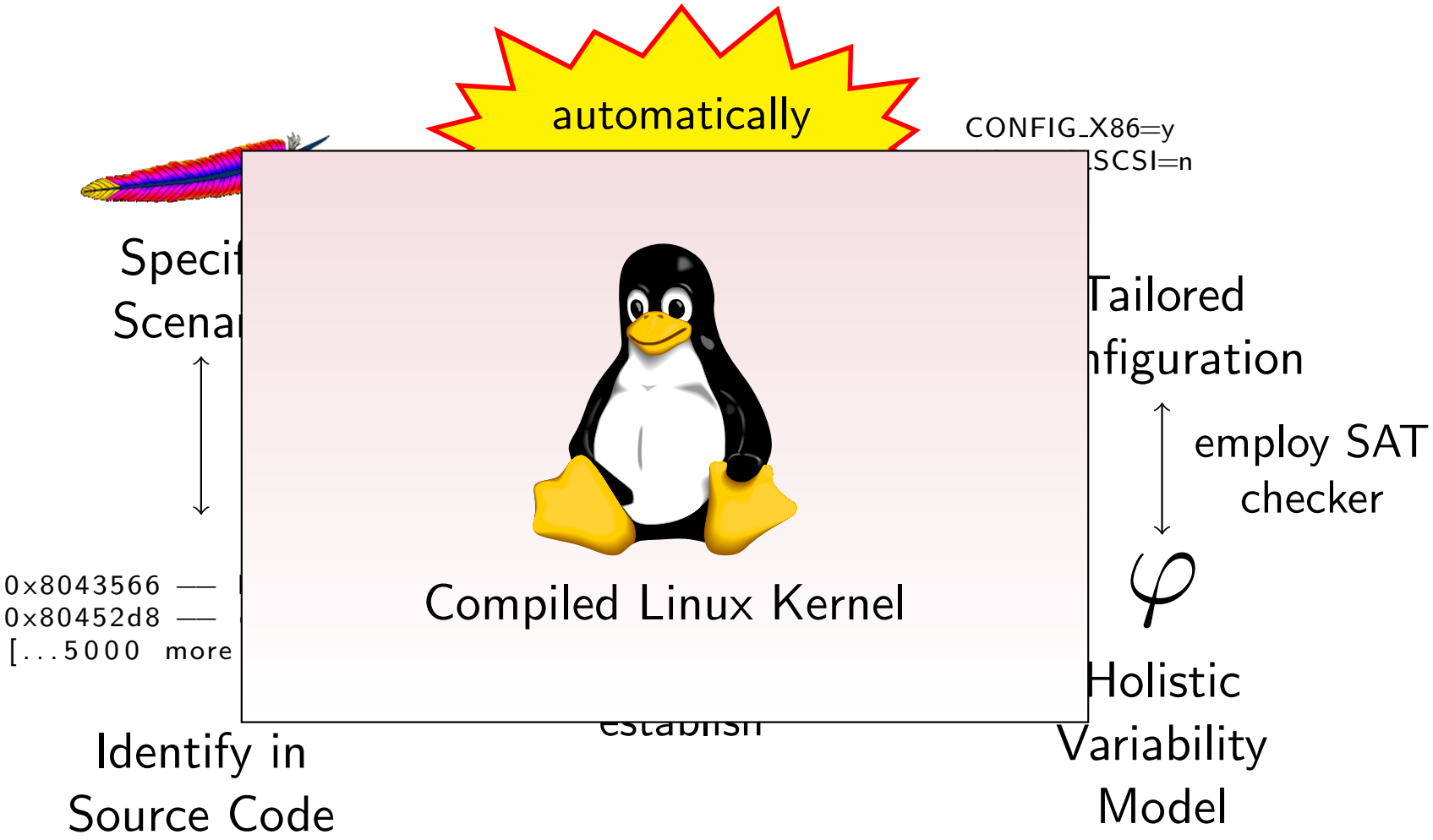

Challenges

- Trace the required functionality from the application
  - Traces need to be sufficiently complete

→ Best results with *fairly homogeneous services*

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- The holistic variability model must include constraints from:
  - KCONFIG feature dependencies among each other
  - MAKE files (→ what KCONFIG feature compiles this file)
  - complicated CPP expressions and nested `#ifdef` blocks

  → solved in previous work by the UNDERTAKER tool

Evaluation

- Standard LAMP (Linux, MySQL, Apache, PHP) System
  - Standard setup with DOKUWIKI and PHPBB3
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- Trace contains 5.377 unique kernel functions
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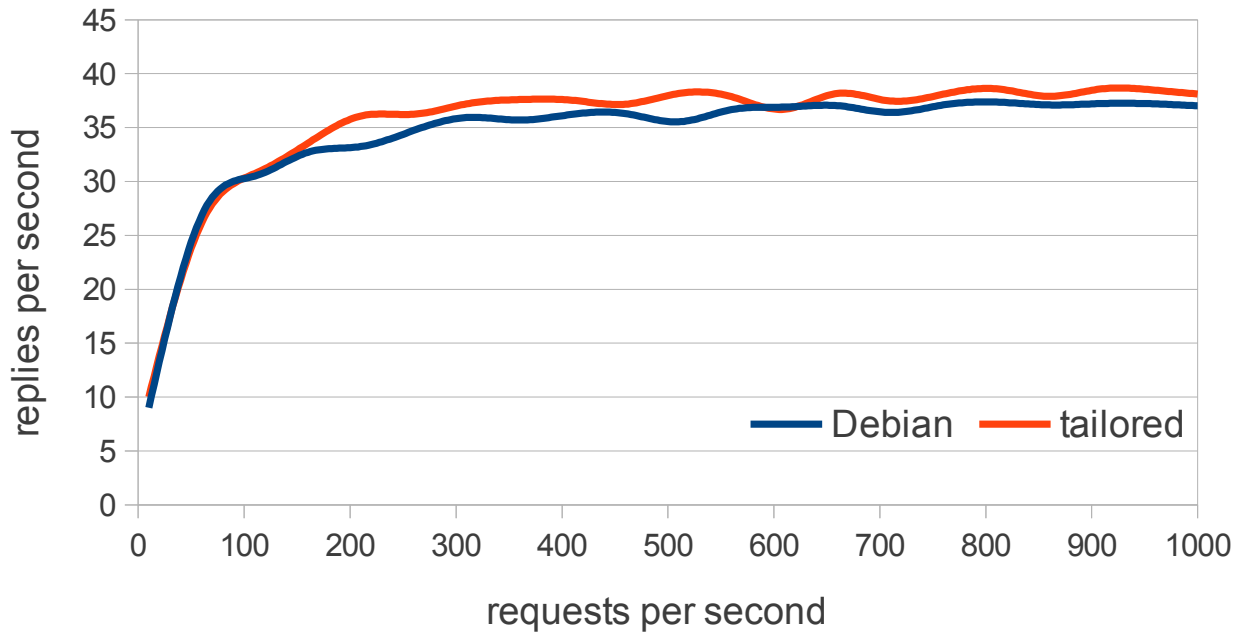

Reduction of enabled features

Kernel Shipped by Debian	
Loaded Kernel Modules	29
KCONFIG options set to `y`	1,093
KCONFIG options set to `m`	2,299
Functions with CVE entries	179
Intermediary kernel used for tracing	
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$\rightarrow$ 10 percent less functions with known vulnerabilities
(using a semi-automated process to scan published CVE issues)

Code Reduction

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Loaded Code	5,465,602 Bytes
Total Loadable Code	42,188,538 Bytes
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Results and Future Work

- TCB is significantly smaller
- Easy to use: process is fully automated after tracing
- If necessary, the tailoring can guided with whitelists and blacklists
- Going further:
  - More use-cases, also on *real hardware*
  - Necessity of dedicated kernel for tracing?
  - What config option shall be configured as module and what statically?
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Questions?