Between the Lines: VM Assumptions

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Tratt

Software Development Team
2020-01-27

What happens if we’re wrong?

VM development is a destination

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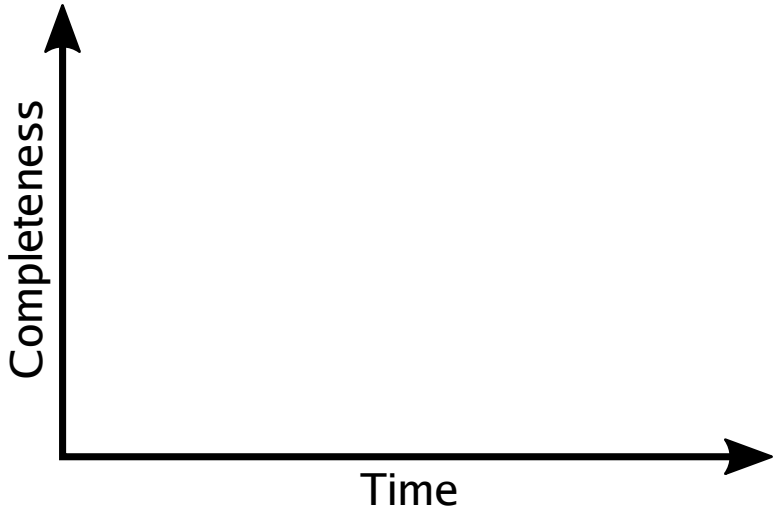

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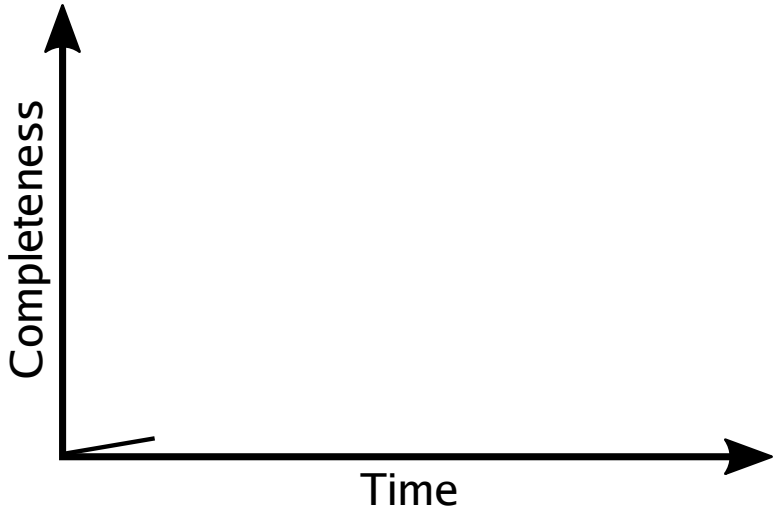

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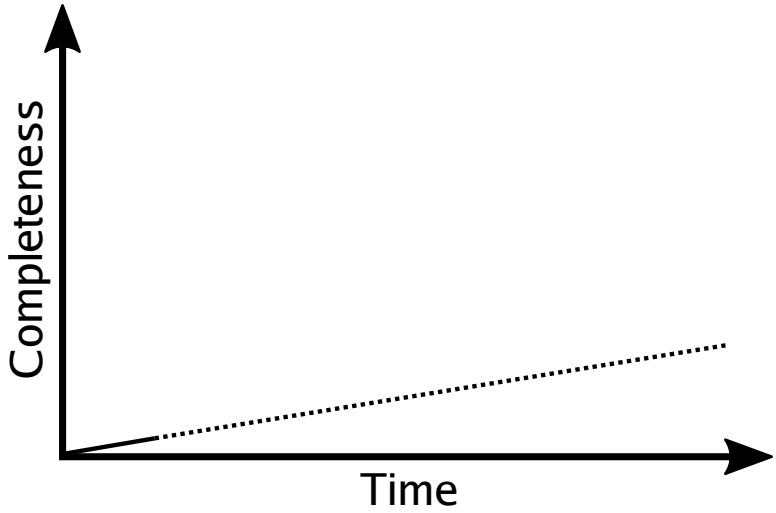

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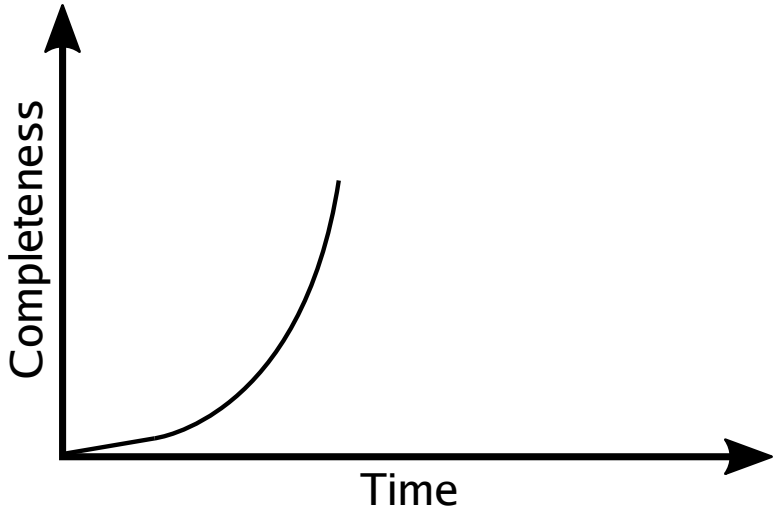

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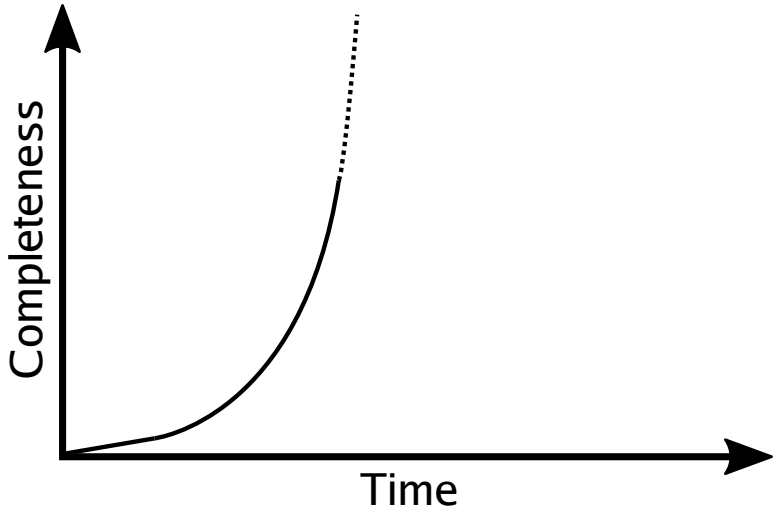

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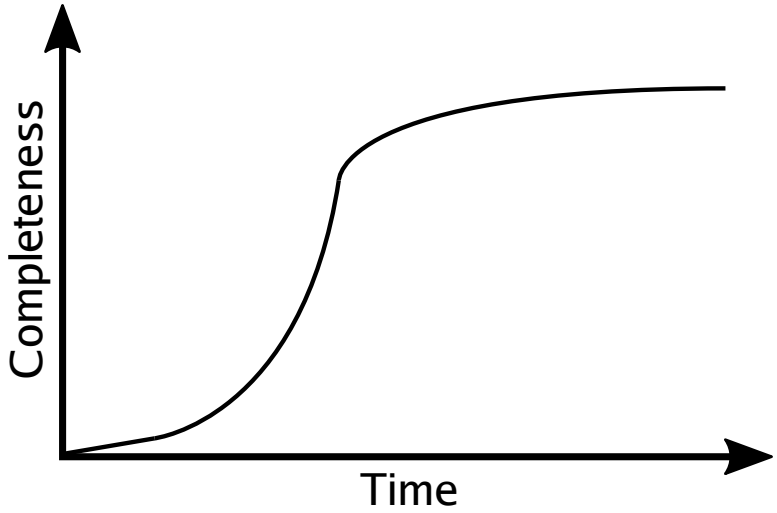

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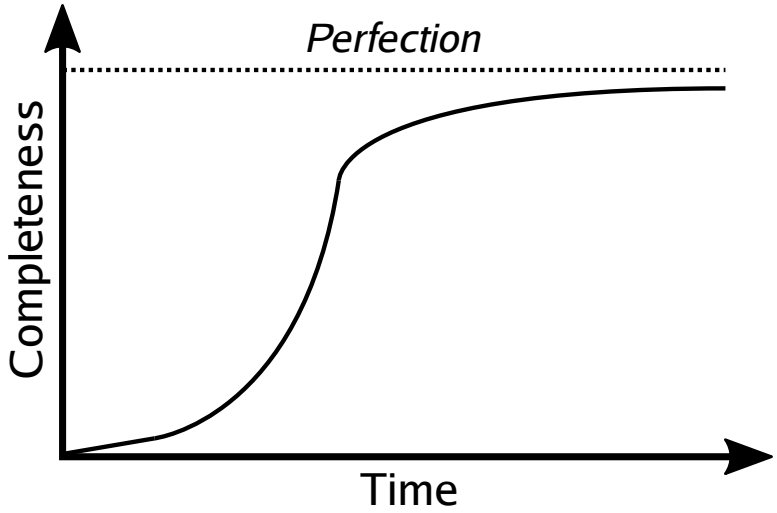

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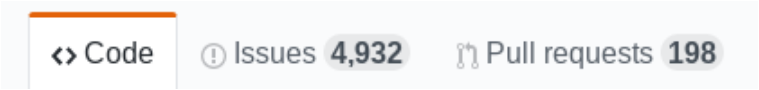
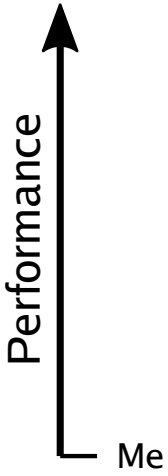


VM development is a never-ending process

We know where the performance ceiling is

What is the best possible performance
for an input *P*?

We know where the performance ceiling is



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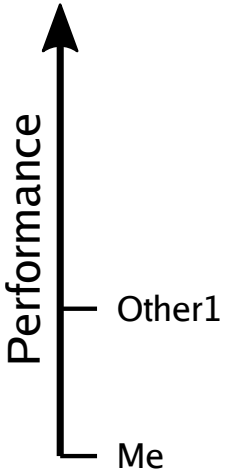

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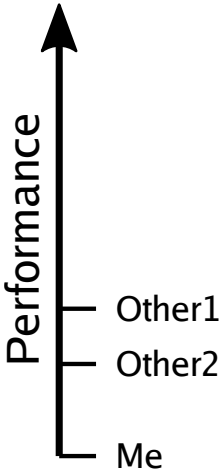

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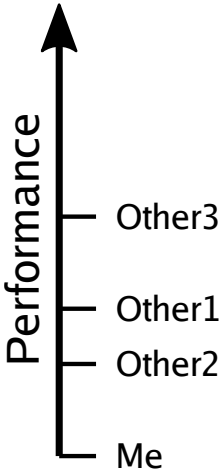

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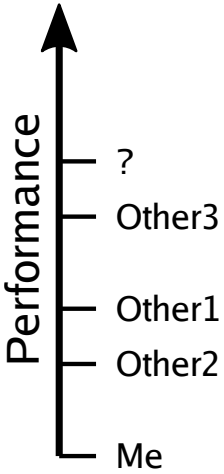

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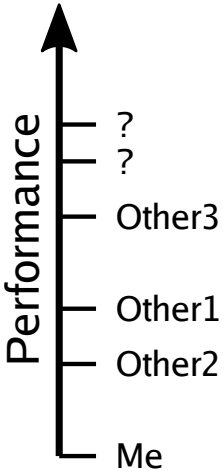

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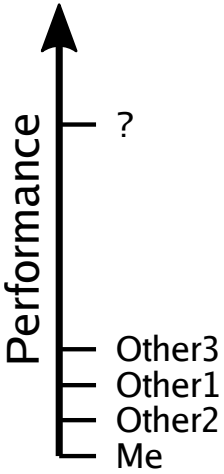

We don’t know how well we’re doing

We’re good at optimising abstractions

Most optimisations are ad-hoc and/or unpredictable

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e.g. mono $\rightarrow$ poly $\rightarrow$ megamorphic JS calls

How to communicate optimisations to users?

We know what the impact of individual features is

What is the effect of e.g. pointer tagging?

What is the effect of e.g. pointer tagging?

GC and register allocation only
fairly deeply studied topics?

Hardware

We know what the impact of individual features is

Hardware: caches

We know what the impact of individual features is

Hardware: caches, predictors

We know what the impact of individual features is

Hardware: caches, predictors, temperature

We know what the impact of individual features is

Hardware: caches, predictors, temperature, etc.

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OS

We know what the impact of individual features is

Hardware: caches, predictors, temperature, etc.

OS: other processes

We know what the impact of individual features is

Hardware: caches, predictors, temperature, etc.

OS: other processes, context switches

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VM

We know what the impact of individual features is

Hardware:	caches, predictors, temperature, etc.
OS:	other processes, context switches, etc.
VM:	compilation heuristics

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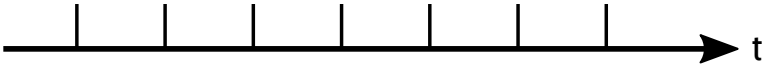
We know what the impact of individual features is

Hardware:	caches, predictors, temperature, etc.
OS:	other processes, context switches, etc.
VM:	compilation heuristics, GC heuristics, etc.

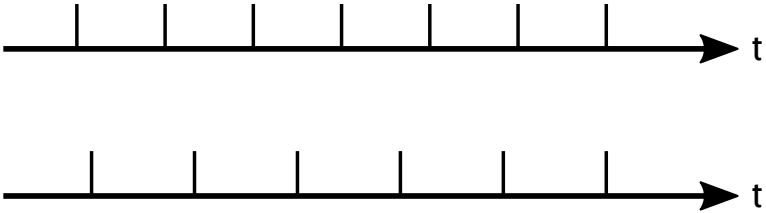
Performance non-determinism is rife

Performance non-determinism

Performance non-determinism



Performance non-determinism



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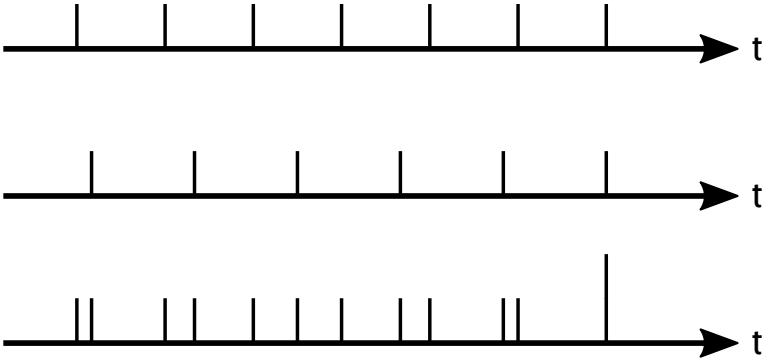

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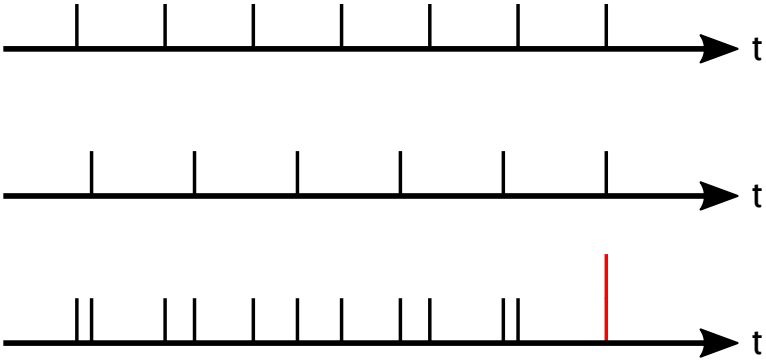


Solution to performance non-determinism

Solution to performance non-determinism:
non-determinism?

We understand how large systems perform

Microbenchmarks behave poorly

Microbenchmarks behave poorly

But that doesn’t affect big benchmarks

How convenient!

What about compositionality?

Multi-language VMs

VMs are expensive to create

VMs are expensive to create

Why not reuse that hard work?

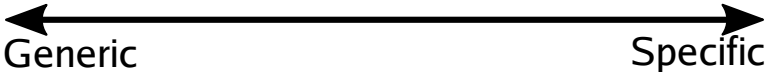
VMs are expensive to create

Why not reuse that hard work?

CPython vs. Jython parable

Semantic mismatch

Semantic mismatch



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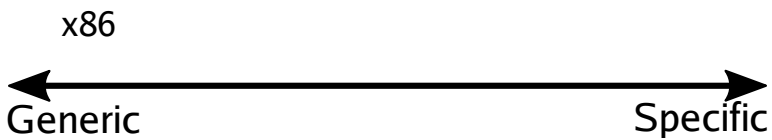

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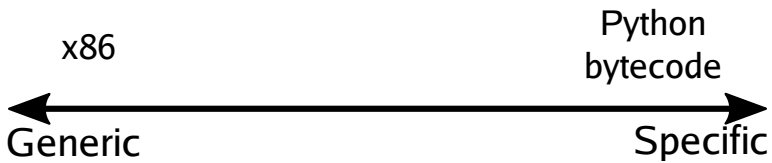

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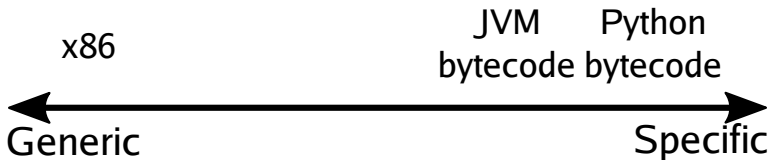

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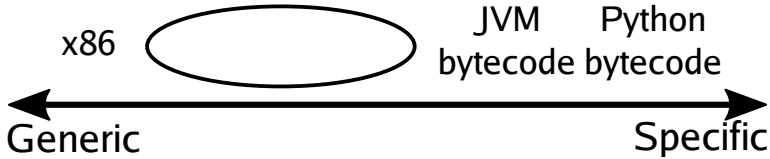

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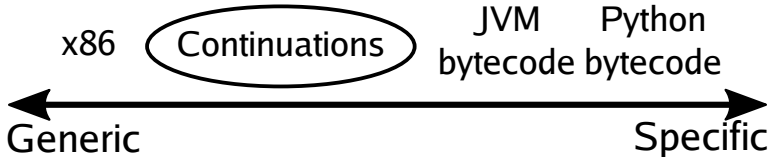

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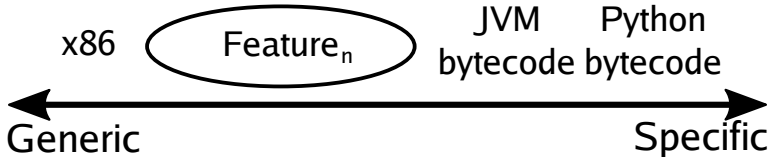

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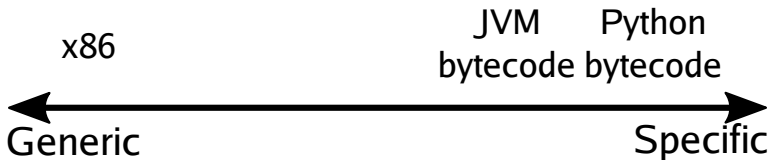

Semantic mismatch

One solution: language design tweaks

WASM will not solve the semantic mismatch

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Meta-VMs suffer much less

My benchmark suite is good, yours is bad

Fix memory leak in pdfjs.js. #42

ltratt wants to merge 2 commits into `chromium:master` from `ltratt:master`

Conversation **7** Commits **2** Checks **0** Files changed **1**

ltratt commented on Oct 2, 2016 • edited

A large amount of data is pushed into the global variable `canvas_logs` which isn't cleared in runPdfJS. On each iteration the list grows, eventually significantly so.

On a Linux machine with a recent-ish V8, it manages 2777 iterations before an allocation fails (at which point it's allocated over 2GiB of virtual memory, and used about 1.4Gib) and V8 crashes (`Fatal error in CALL_AND_RETRY_LAST`).

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natorion commented on Feb 7, 2018 • edited — Member

It won't be merged. Octane is retired and no longer maintained. Sorry for the long communication cycle.

natorion closed this on Feb 7, 2018

A year with Spectre: a V8 perspective

Published 23 April 2019 · tagged with security

On January 3, 2018, Google Project Zero and others disclosed the first three of a new class of vulnerabilities that affect CPUs that perform speculative execution, dubbed Spectre and Meltdown. Using the speculative execution mechanisms of CPUs, an attacker could temporarily bypass both implicit and explicit safety checks in code that prevent programs from reading unauthorized data in memory. While processor speculation was designed to be a microarchitectural detail, invisible at the architectural level, carefully crafted programs could read unauthorized information in speculation and disclose it through side channels such as the execution time of a program fragment.

▪

▪

▪

We have experimented with (1) by inserting the recommended speculation barrier instructions, such as Intel's `LFENCE`, on every critical conditional branch, and by using retpolines for indirect branches. Unfortunately, such heavy-handed mitigations greatly reduce performance (2–3× slowdown on the Octane benchmark). Instead, we chose approach (2), inserting mitigation sequences that prevent reading secret data due to mis-speculation. Let us illustrate the technique on the following code snippet:

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My benchmark suite is good, yours is bad

Benchmark suites a finite representation of infinite behaviour

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All benchmark suites are imperfect

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We need more and more benchmarks!

Managed languages are safe

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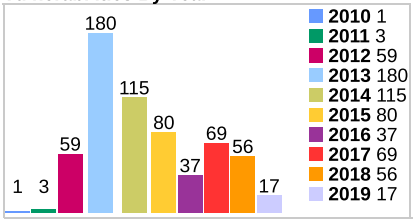
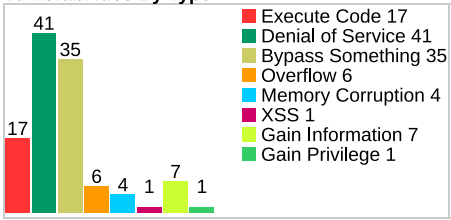
Vulnerabilities By Year



Vulnerabilities By Type



Source: https://www.cvedetails.com/product/19117/Oracle-JRE.html?vendor_id=93

C/C++ aren’t very safe

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And what about JITted code?

C/C++ aren't very safe

And what about JITted code?

Prediction: VM security apocalypse is possible

We’re stuck with C/C++

What about Rust?

What about Rust?

Not an obvious fit for VMs

What about Rust?

Not an obvious fit for VMs

Can we make it so?

VMs use dynamic dispatch extensively

VMs use dynamic dispatch extensively

```
use std::mem::size_of;

trait T { }

fn main() {
  assert_eq!(size_of::<&bool>(), size_of::<&u128>());
  assert_eq!(size_of::<&bool>(), size_of::<usize>());
  assert_eq!(size_of::<&dyn T>(), size_of::<usize>() * 2);
}
```

Thin pointers for dynamic dispatch

```
let x: &dyn T = ...;
let (ptr, vtable) = unsafe {
  mem::transmute<_, (*mut u8, *mut u8)>(x)
};
```

Thin pointers for dynamic dispatch

```
#[repr(C)]
struct ThinPtr { objptr: *mut u8 }

impl ThinPtr {
  fn new<U>(o: U) -> ThinPtr
    where *const U: CoerceUnsized<*const (dyn T + 'static)>,
          U: T + 'static
  {
    let (dataptr, vtable) = unsafe { mem::transmute<_, (*mut u8, *mut u8)>(x) };
    let objptr = malloc(size_of::<*mut u8>() + size_of::<U>());
    unsafe { ptr::write(objptr, &vtable, size_of::<*mut u8>()) };
    unsafe { ptr::write(objptr + 1, ptr, size_of::<U>()) };
    ThinPtr { objptr }
  }
}

impl Deref for ThinPtr {
  type Target = dyn T;
  fn deref(&self) -> &(dyn T + 'static) {
    let vtable = unsafe { ptr::read(objptr, size_of::<*mut u8>()) };
    unsafe { transmute::<(*const _, *const _), _>((self.objptr + 1, vtable)) }
  }
}
```

Thin pointers for dynamic dispatch

```
#[repr(C)]
struct ThinPtr { objptr: *mut u8 }

impl ThinPtr {
  fn try_downcast<U: T>(&self) -> Option<&U> {
    let t_vtable = unsafe {
      transmute::<&dyn T, (*mut u8, *mut u8)>(ptr::null() as *const U) };
    let vtable = unsafe { ptr::read(objptr, size_of::<*mut u8>()) };
    if vtable == t_vtable {
      Some(unsafe { &* (self.objptr + 1) as *const U })
    } else {
      None
    }
  }
}
```

Thin pointers for dynamic dispatch

```
#[narrowable_abgc(ThinObj)]
trait Obj { }

struct VMInt { x: u64 }

impl Obj for VMInt { }

fn f(v: ThinObj) {
  if let Some(o) = v.try_downcast::<VMInt>() {
    println!(o.x);
  }
}
```

Can we use Rust for VMs?

So far, so good

So far, so good

Major challenge: idiomatic GC support

The security landscape is changing

CHERI:

CHERI: capabilities in 128-bit pointers

We’re good at explaining what we do

IronPython; Jython; Nuitka; Psyco; PyPy; Pyston; Shed Skin; Stackless; Starkiller; TrufflePython; Unladen Swallow; WPython; Zippy

IronPython; Jython; Nuitka; Psyco; PyPy; Pyston; Shed Skin; Stackless; Starkiller; TrufflePython; Unladen Swallow; WPython; Zippy

e.g. compiling to LLVM fails every time...

We often pretend trade-offs don't exist

We often pretend trade-offs don't exist

Huge burden for newcomers to the field

Where can we go next?

We understand less than we should

Clear problems

Opportunities!

Thanks for listening