Overview

• Language designers curse...
• ...to meta-tracing...
• ...to using Rust for Yk.
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- ...to meta-tracing...
- ...to using Rust for Yk.
Why?

• Language implementation is arduous.
• 'Semantic mismatch' is real – and common.
• Bad design or bad implementation?
• 'Good enough' performance is good enough.
• Let's free language designers to experiment!
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Traditional VMs
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Hand-written interpreter
Traditional VMs

Hand-written interpreter

& hand-written JIT.
Hand-written interpreter
Hand-written interpreter & get a JIT for free.
Meta-tracing JITs

**FL Interpreter**

```python
pc = 0; stack = []
vars = {...}
while True:
    if control_point(pc):
        continue
    instr = load_instruction(pc)
    if instr == INSTR_VAR_GET:
        stack.push(
            vars[read_var_name_from_instruction()]
        )
        pc += 1
    elif instr == INSTR_VAR_SET:
        vars[read_var_name_from_instruction()] = stack.pop()
        pc += 1
    elif instr == INSTR_INT:
        stack.push(read_int_from_instruction())
        pc += 1
    elif instr == INSTR_LESS_THAN:
        rhs = stack.pop()
        lhs = stack.pop()
        if isinstance(lhs, int) and isinstance(rhs, int):
            if lhs < rhs:
                stack.push(True)
                pc += 1
            else:
                pc += 1
        else: ...
        pc += 1
    elif instr == INSTR_IF:
        result = stack.pop()
        if result == True:
            pc += 1
        else:
            pc += read_jump_if_instruction()
    elif instr == INSTR_ADD:
        lhs = stack.pop()
        rhs = stack.pop()
        if isinstance(lhs, int) and isinstance(rhs, int):
            stack.push(lhs + rhs)
            pc += 1
        else: ...
        pc += 1
```
Delta-tracing JITs

**FL Interpreter**

```python
cp = 0; stack = []
vars = {...}
while True:
    if control_point(cp):
        continue
    instr = load_instruction(pc)
    if instr == INSTR_VAR_GET:
        stack.append(vars[read_var_name_from_instruction()] cp += 1
    elif instr == INSTR_VAR_SET:
        vars[read_var_name_from_instruction()] = stack.pop()
        pc += 1
    elif instr == INSTR_INT:
        stack.append(read_int_from_instruction()) pc += 1
    elif instr == INSTR_LESS_THAN:
        rhs = stack.pop()
        lhs = stack.pop()
        if isinstance(lhs, int) and isinstance(rhs, int):
            if lhs < rhs:
                stack.append(True)
            else:
                stack.append(False)
        else: ...
        pc += 1
```
Meta-tracing JITs

**FL Interpreter**

```python
cp = 0; stack = []
vars = {...}
while True:
    if control_point(pc):
        continue
    instr = load_instruction(pc)
    if instr == INSTR_VAR_GET:
        stack.push(vars[read_var_name_from_instruction()])
        pc += 1
    elif instr == INSTR_VAR_SET:
        vars[read_var_name_from_instruction()] = stack.pop()
        pc += 1
    elif instr == INSTR_INT:
        stack.push(read_int_from_instruction())
        pc += 1
    elif instr == INSTR_LESS_THAN:
        rhs = stack.pop()
        lhs = stack.pop()
        if isinstance(lhs, int) and isinstance(rhs, int):
            if lhs < rhs:
                stack.push(True)
            else:
                stack.push(False)
        else:
            ...  # elsewhere
        pc += 1
```

**User program (lang FL)**

```python
if x < 0:
    x = x + 1
else:
    x = x + 2
x = x + 3
```
**FL Interpreter**

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pc = 0; stack = []
vars = {...}
while True:
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        continue
    instr = load_instruction(pc)
    if instr == INSTR_VAR_GET:
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        pc += 1
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        rhs = stack.pop()
        lhs = stack.pop()
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            if lhs < rhs:
                stack.push(True)
            else:
                stack.push(False)
        else: ...
        pc += 1
```

**Initial trace**

```python
v0 = <pc>
v1 = <stack>
v2 = <vars>
v3 = load_instruction(v0)
guard_eq(v3, INSTR_VAR_GET)
v4 = dict_get(v2, "x")
list_append(v1, v4)
v5 = add(v0, 1)
v6 = load_instruction(v5)
guard_eq(v6, INSTR_INT)
list_append(v1, 0)
v7 = add(v5, 1)
v8 = load_instruction(v7)
guard_eq(v8, INSTR_LESS_THAN)
v9 = list_pop(v1)
v10 = list_pop(v1)
guard_type(v9, int)
guard_type(v10, int)
guard_not_less_than(v9, v10)
list_append(v1, False)
v11 = add(v7, 1)
v12 = load_instruction(v11)
guard_eq(v12, INSTR_IF)
v13 = list_pop(v1)
guard_false(v13)
...
What language?

- RPython?
- C/C++?
- Java?
- Rust!
What language?

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- Rust!
Rust for meta-tracing: pros

• Good balance between performance and safety.
• Vibrant & growing community.
• High quality, modern, compiler.
• Doesn't impose an inappropriate GC strategy.
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Rust for meta-tracing: cons

- Incomplete specification.
- Upstream struggling with community growth?
- Language big and still growing.
- Internal compiler churn.
- Difficult to use for GC'd languages.
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Language spec

Language reference:
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**UnsafeCell:**
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UnsafeCell: “The precise Rust aliasing rules are somewhat in flux, but the main points are not contentious”
Stacked Borrows is excellent work!

Will it become official?

Will Miri be the only sanitizer?
Stacked Borrows is excellent work!
Stacked Borrows is excellent work!

1 Will it become official?
Stacked Borrows is excellent work!

1. Will it become official?
2. Will Miri be the only sanitiser?
Garbage collection: outlines

• Implementing GC'd languages without GC: painful, slow.
• Rust once had a ref-counted GC!
• Many exotic Rust GC libraries.
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Garbage collection

• Unlikely we can retroactively implement 'perfect' GC.
• Conservative GC probably always necessary.
• Our solution: rustgc.
• Boehm is underappreciated.
• Fork rustc for semi-precise GC.
• Safe enough (probably...) with stacked borrows.
• Impose restrictions on minimisers for safety.
Garbage collection

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- Impose restrictions on finalisers for safety.
• Our new Rust meta-tracer: Yk
• Still 'hello world' days!
• Major aim: reduce warm-up.
• Trace basic blocks; use Intel PT (or equivalent).
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ykrustc

• (another) rustc fork.
• rustc: HIR → MIR → machine code.
• ykrustc: HIR → MIR → machine code

compile-time: MIR
run-time: SIR → TIR

JIT → machine code.
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  compile-time: MIR $\rightarrow$ SIR
  run-time: SIR $\rightarrow$ TIR $\rightarrow$ machine code.
  JIT
while {
    if x < 0 {
        x = y + z;
    }
    print(x);
}
#[interp_step]

fn interp(st: &mut InterpCtx) {
    if st.x < 0 {
        st.x = st.y + st.z;
    }
    print(st.x);
}
MIR

bb0: {
    StorageLive(_2);
    StorageLive(_3);
    _3 = ((*_1).0: isize);
    _2 = Lt(move _3, const 0_isize);
    StorageDead(_3);
    switchInt(_2) -> [false: bb1, otherwise: bb2];
}

bb1: {
    goto -> bb4;
}

bb2: {
    StorageLive(_4);
    _4 = ((*_1).1: isize);
    StorageLive(_5);
    _5 = ((*_1).2: isize);
    _6 = CheckedAdd(_4, _5);
    assert(!move (_6.1: bool), "attempt to compute '{} + {}', which would overflow", move _4, move _5) -> bb3;
}

bb3: {
    ((*_1).0: isize) = move (_6.0: isize);
    StorageDead(_5);
    StorageDead(_4);
    goto -> bb4;
}

...
SIR

bb0:
$2 = *$1
$3 = $2 < 0isize
$4 = $3
switch_int $4, [0], [1], 2

bb1:
goto bb4

bb2:
$5 = *($1)+8
$6 = *($1)+16
$7 = $5 + $6 (checked)
$8 = $7
assert $8+8, 3

bb3:
*$1 = $8
goto bb4

bb4:
$9 = *$1
$10 = call print($9) -> bb5

bb5:
$0 = ()
return
$2 = *$1
$3 = $2 < isize
dead($2)
$4 = $3
dead($3)
guard($4, other_integer([0]), <interp, 0>, [])
dead($4)
$5 = +($1)+8
$6 = +($1)+16
$7 = $5 + $6 (checked)
dead($5)
dead($6)
$8 = $7
dead($7)
guard($8+8, bool(false), <interp, 2>, [$8])
*$1 = $8
dead($8)
$9 = *$1
$10 = call(print, [$9])
dead($10)
dead($9)
• Roughly: ‘Hello world’ for BF.
• We’re now in the happy phase of implementation!
• Next: SOM.
• Long-term: a ‘Rust language implementation kit’? Pair e.g. with our parsing toolkit.
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Thanks for listening

https://github.com/softdevteam/ykrustc/wiki