V8: Hooking up the Ignition to the Turbofan

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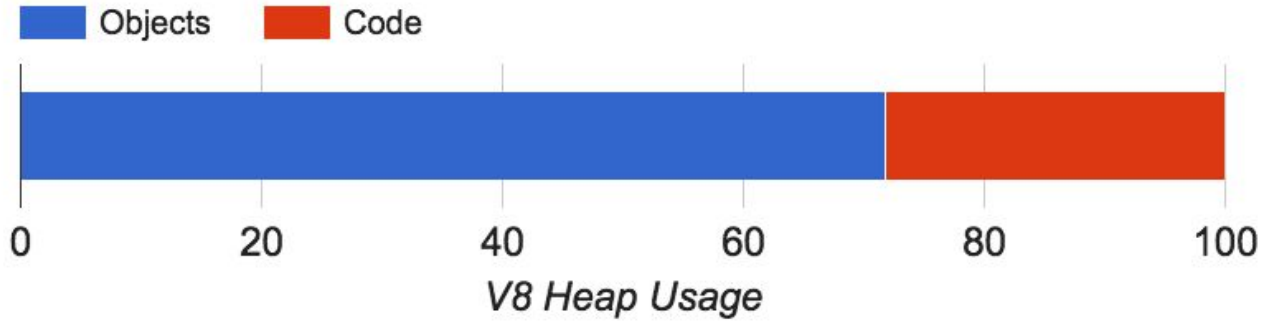
Ignition + Turbofan pipeline

Why a new pipeline?

- Reduce memory usage



Why a new pipeline?

- Reduce memory usage

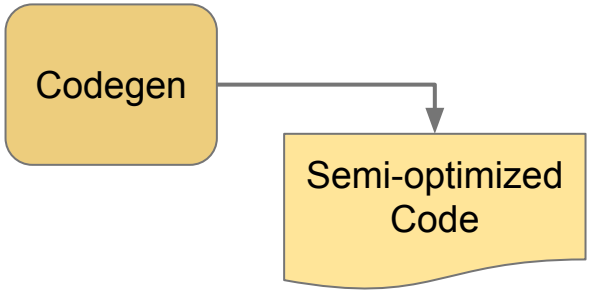
- Reduce startup time

33% of time spent parsing + compiling

Why a new pipeline?

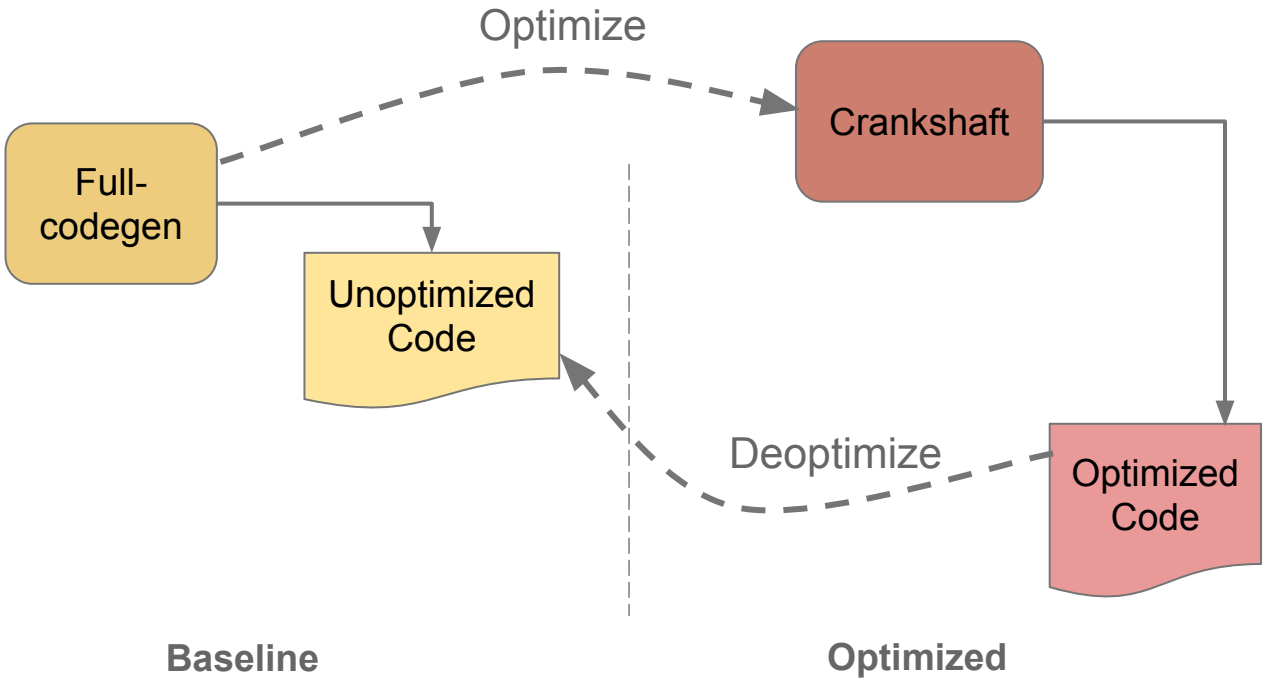
- Reduce memory usage
- Reduce startup time
- Reduce complexity

Compiler Pipeline (2008)

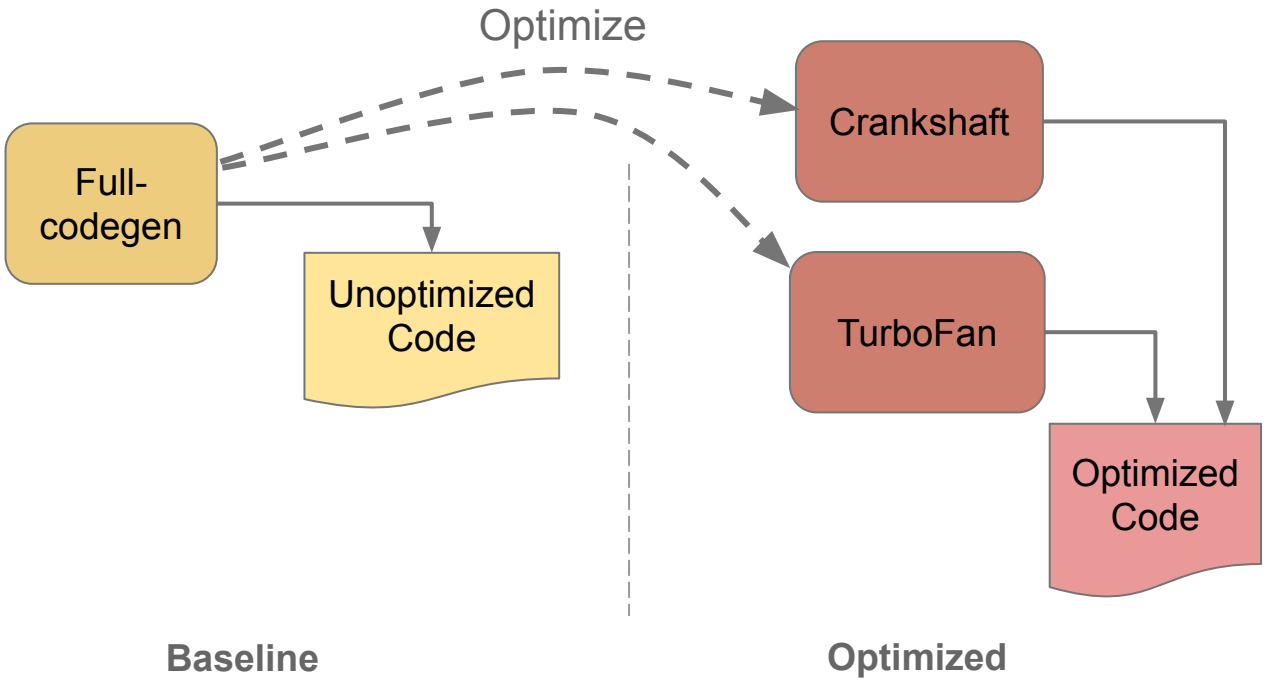


Baseline

Compiler Pipeline (2010)



Compiler Pipeline (2015)



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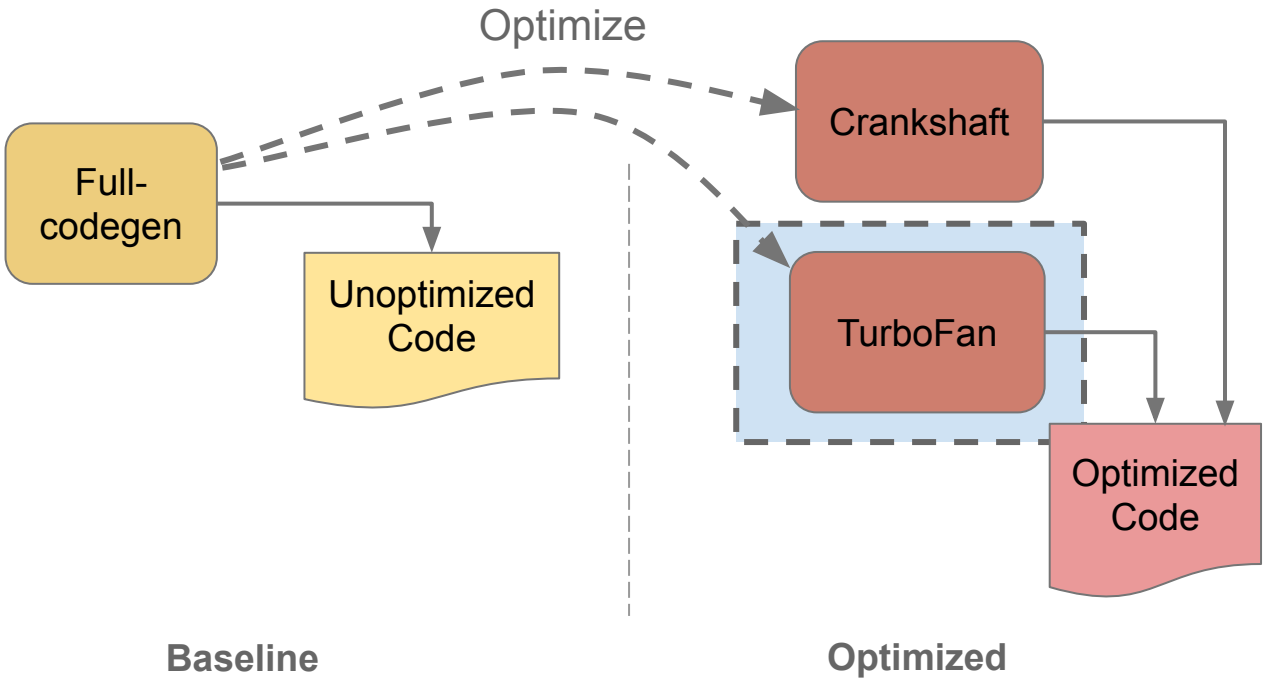
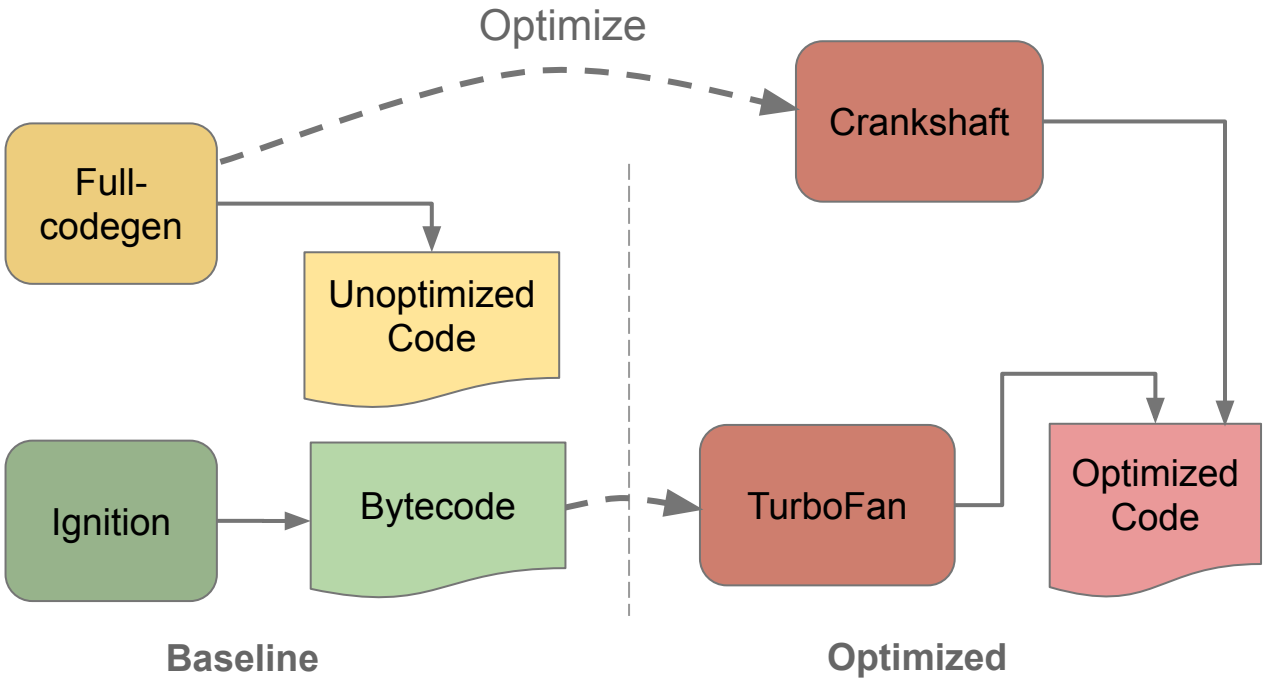


Compiler Pipeline (2016)



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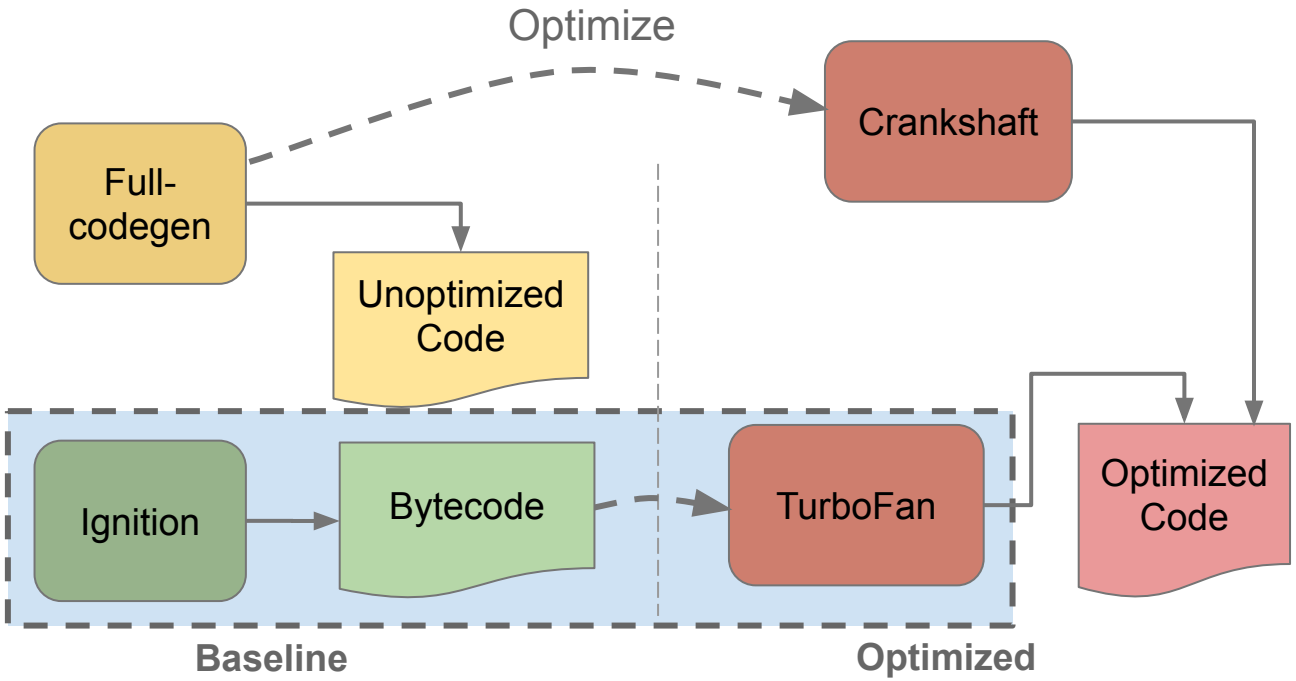
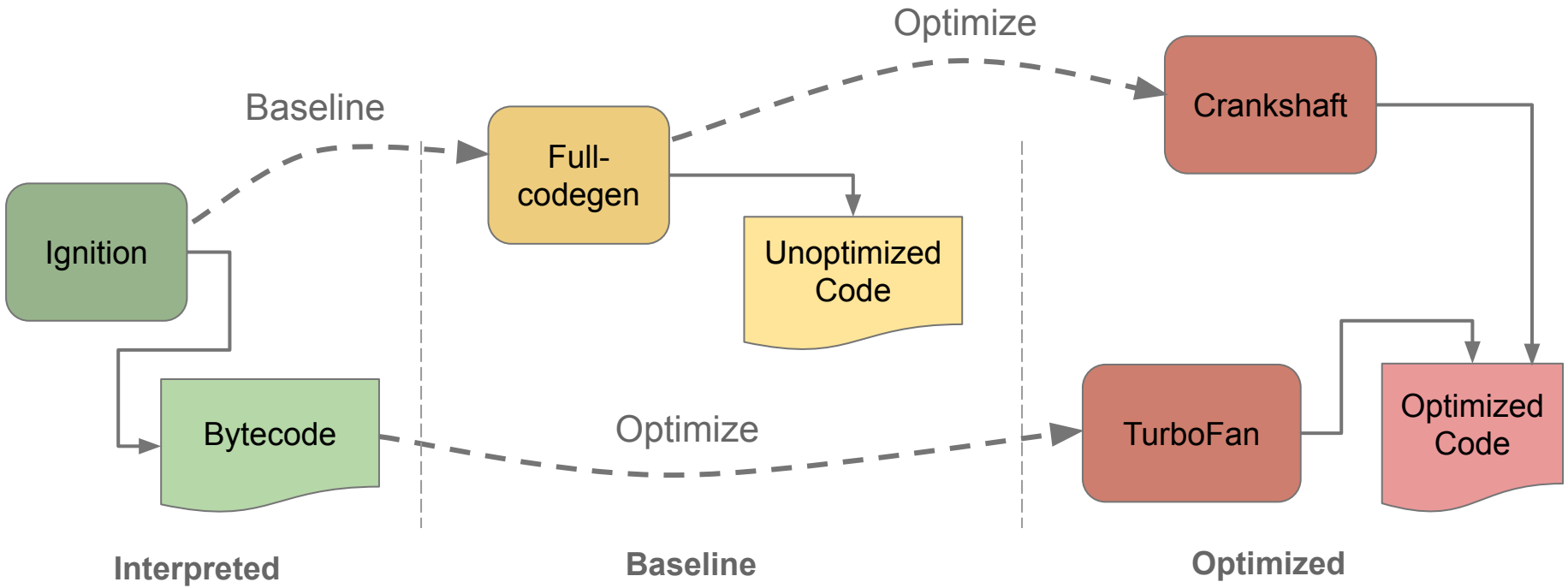


Compiler Pipeline (Svelte Devices)



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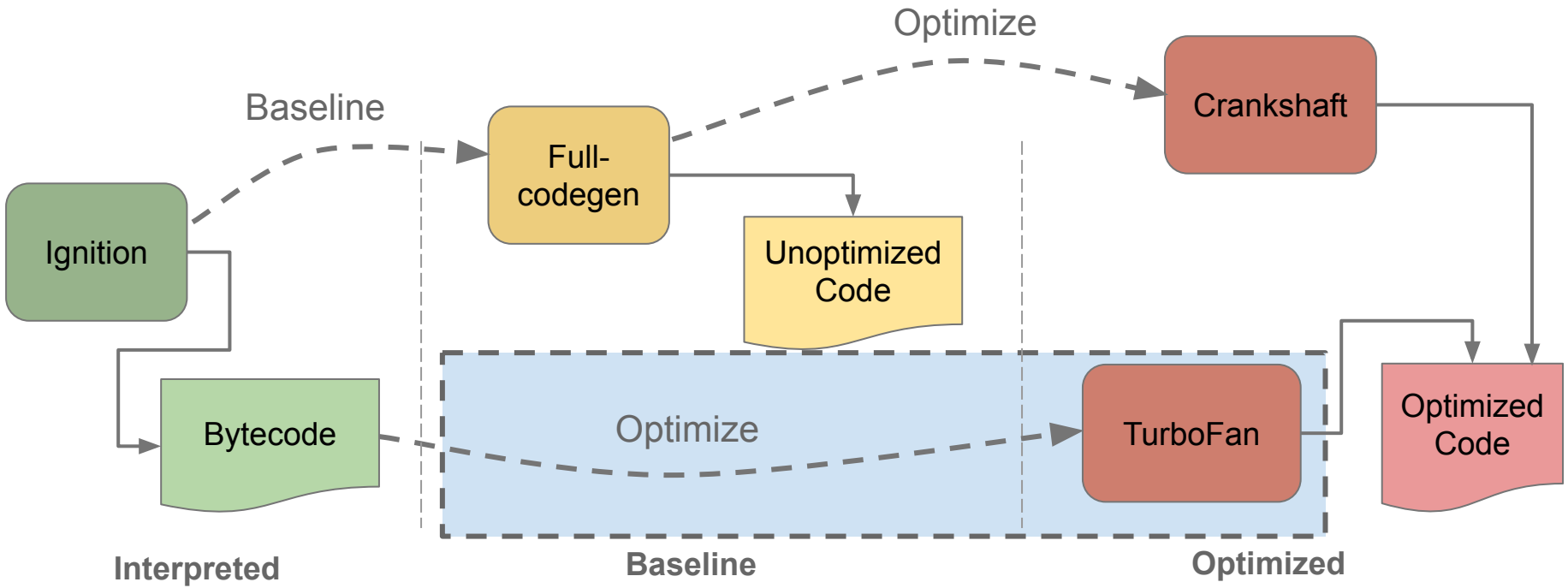
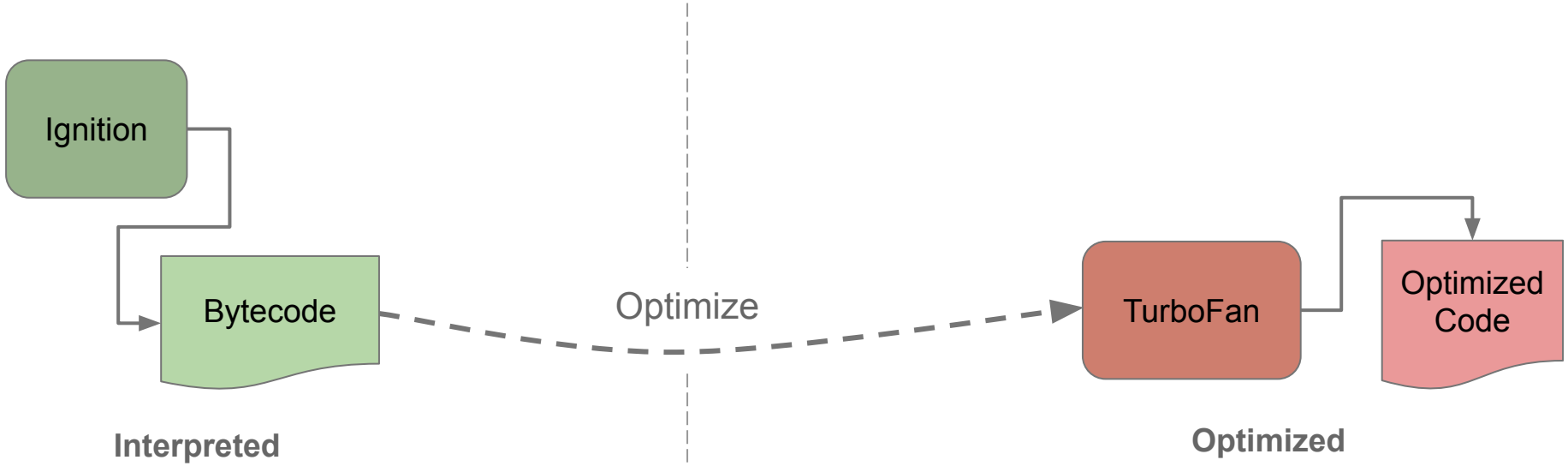


Compiler Pipeline (2017)



Bytecode to graph

Ignition to Turbofan

```
function f(a, b) {
    var result = a + b;
    if (a > b) {
        result = a - b;
    }
    return result;
}
```

```
 0 : 7d          StackCheck
 1 : 1c 02       Ldar a1
 3 : 28 03 02    Add a0, [2]
 6 : 1d fa       Star r0
 8 : 1c 02       Ldar a1
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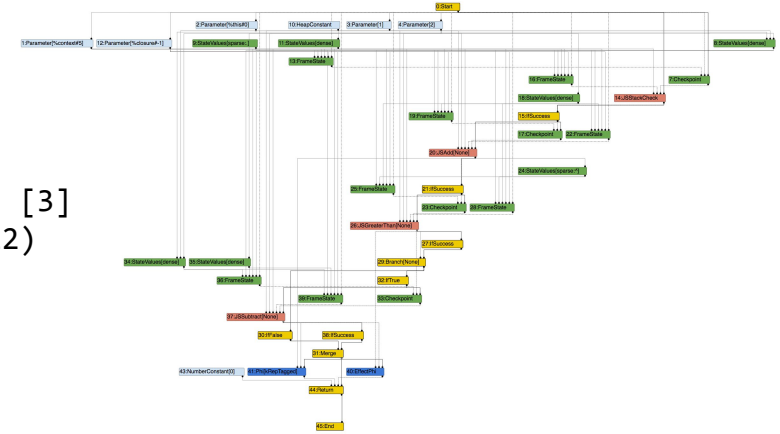

Text

Bytecode (Ignition)

Sea-of-nodes graph (Turbofan)

Executing bytecode

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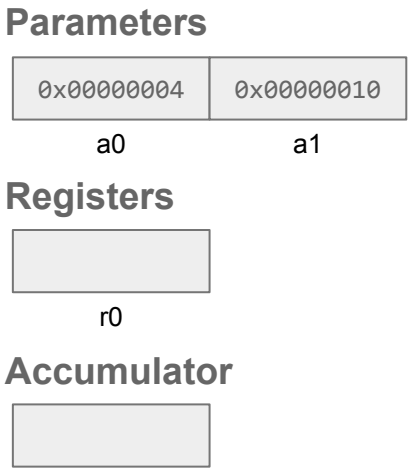

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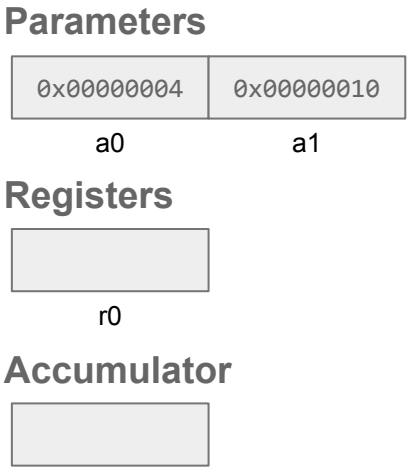

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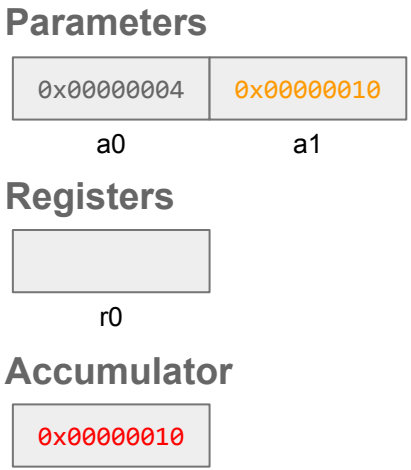

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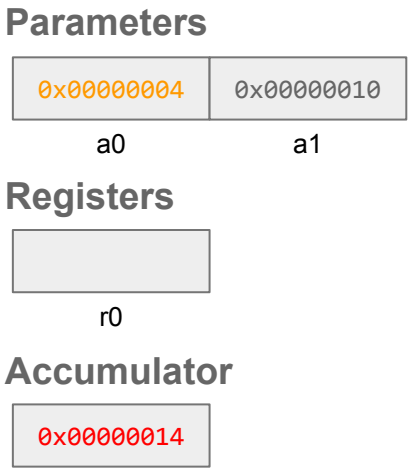

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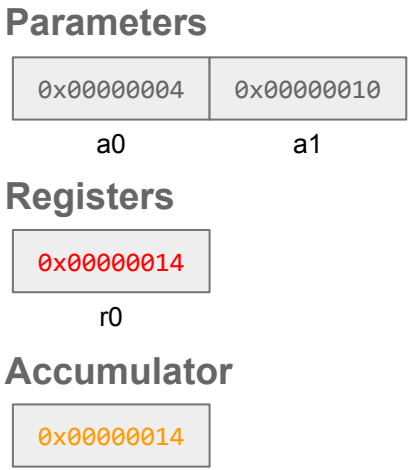

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Parameters

0x00000004	0x00000010
a0	a1

Registers

0x00000014
r0

Accumulator

0x00000010

Executing bytecode

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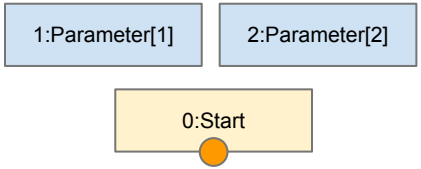
Building a graph

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Registers

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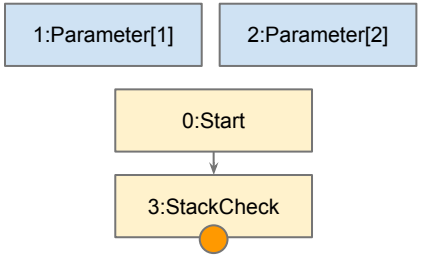


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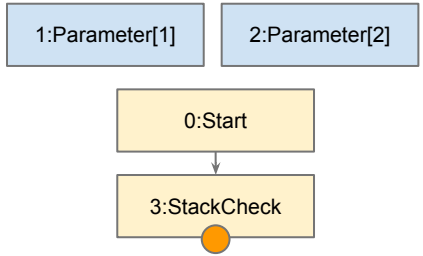


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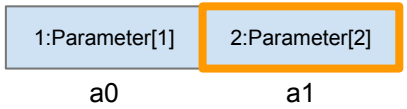

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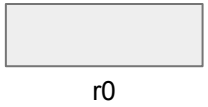

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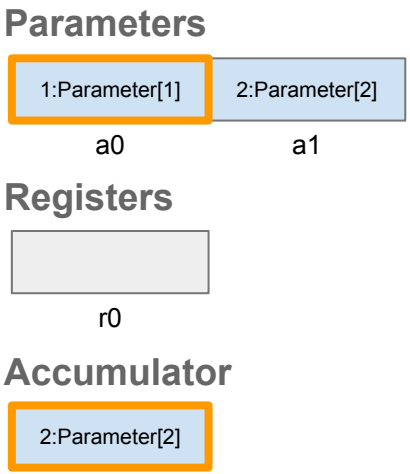

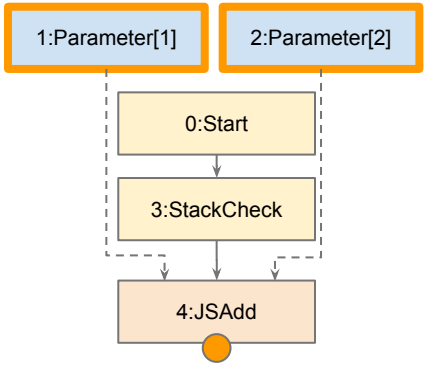

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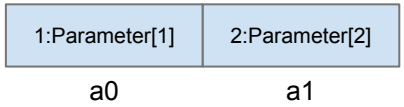

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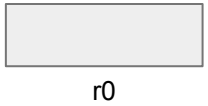

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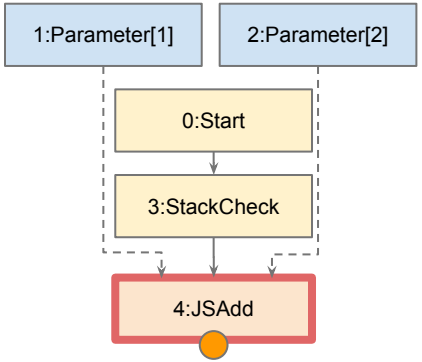

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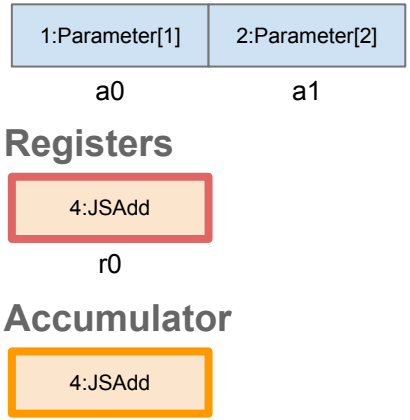

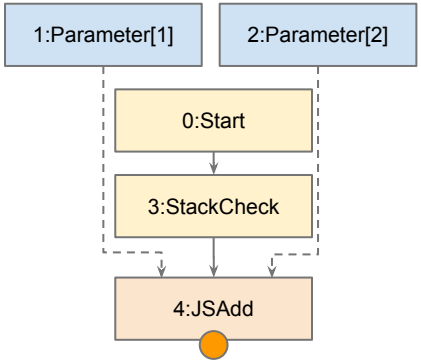

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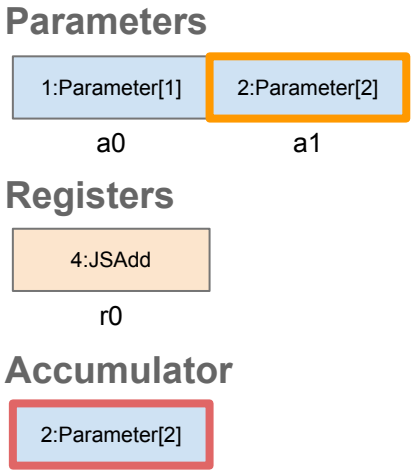

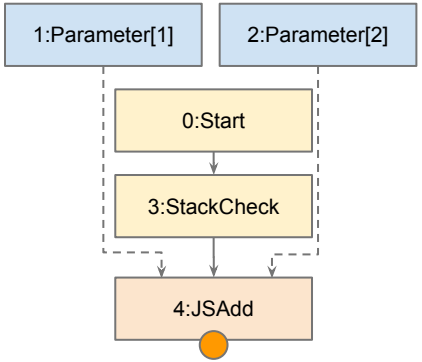

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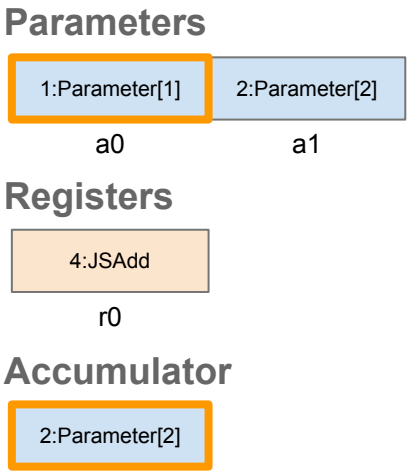

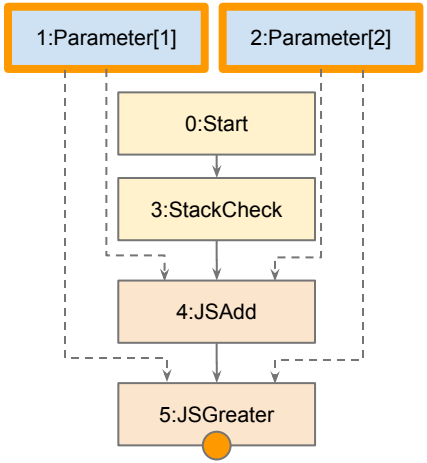

Building a graph

```
  0 : 7d          StackCheck
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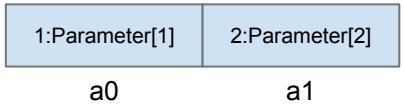
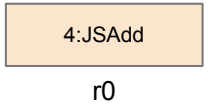
  3 : 28 03 02    Add a0, [2]
  6 : 1d fa       Star r0
  8 : 1c 02       Ldar a1
 10 : 4f 03 03    TestGreaterThan a0, [3]
 13 : 74 09       JumpIfFalse [9] (@22)
 15 : 1c 02       Ldar a1
 17 : 29 03 04    Sub a0, [4]
 20 : 1d fa       Star r0
 22 : 1c fa       Ldar r0
 24 : 81          Return
```

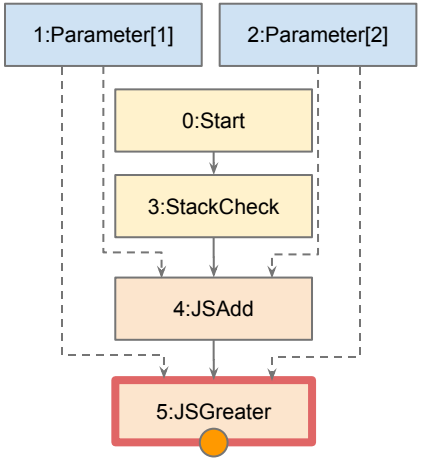
Parameters



Registers



Accumulator



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22 : 1c fa     Ldar r0
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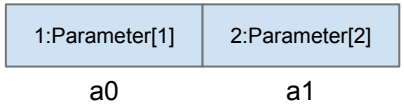
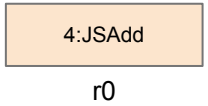
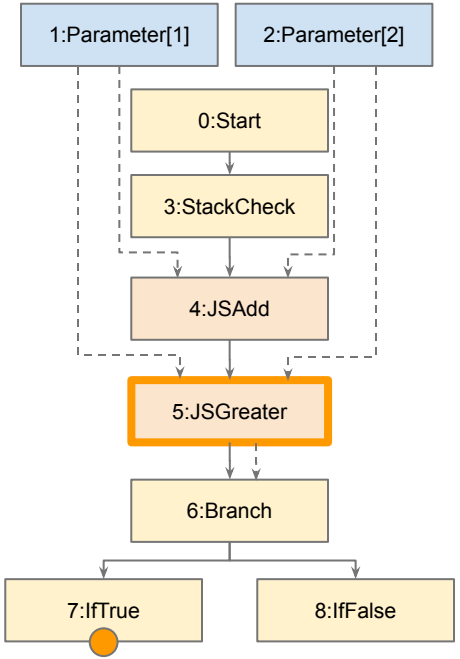
Parameters



Registers



Accumulator



Building a graph

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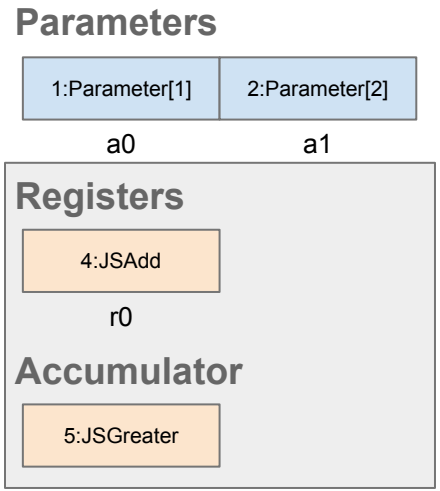
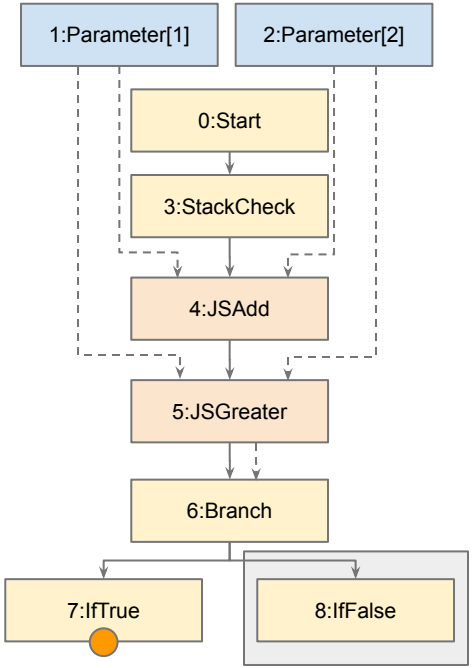
24 : 81          Return
```





Building a graph

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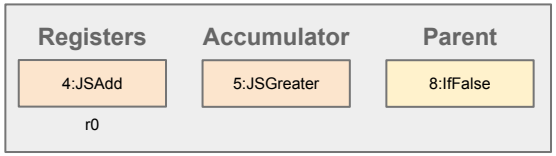
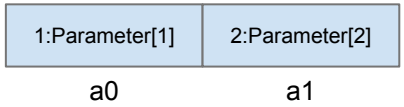
20 : 1d fa     Star r0
22 : 1c fa     Ldar r0
24 : 81        Return
```

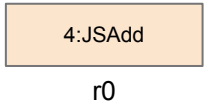
22:



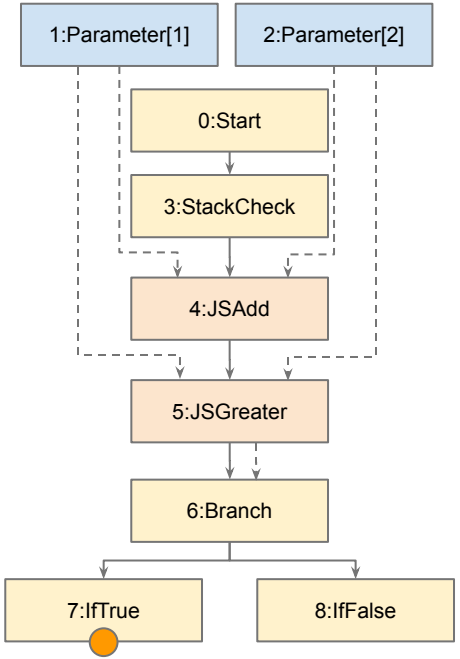
Parameters



Registers



Accumulator



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 22 : 1c fa     Ldar r0
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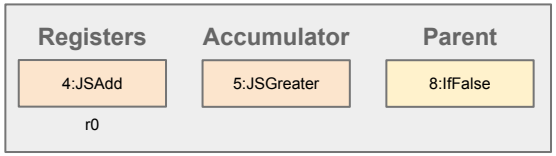
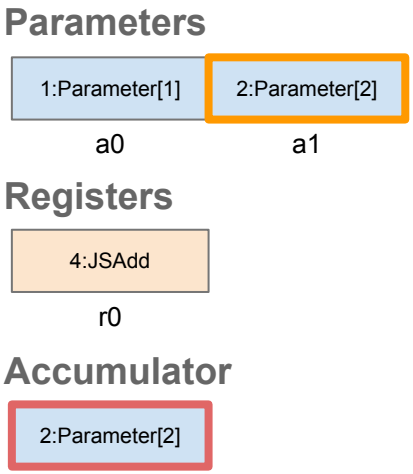
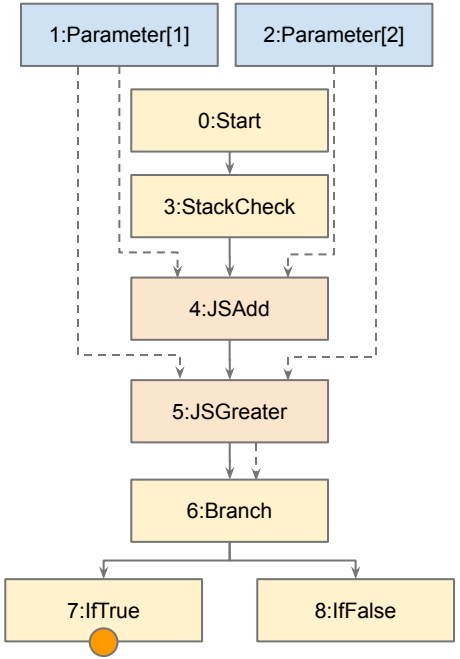
```

22:







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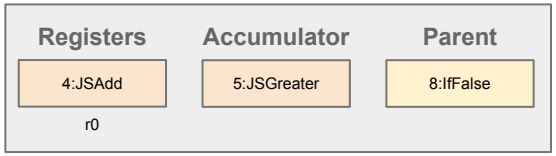

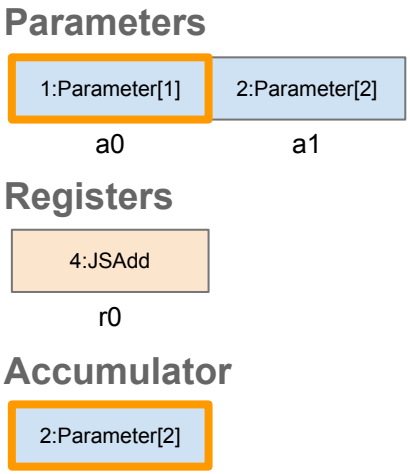

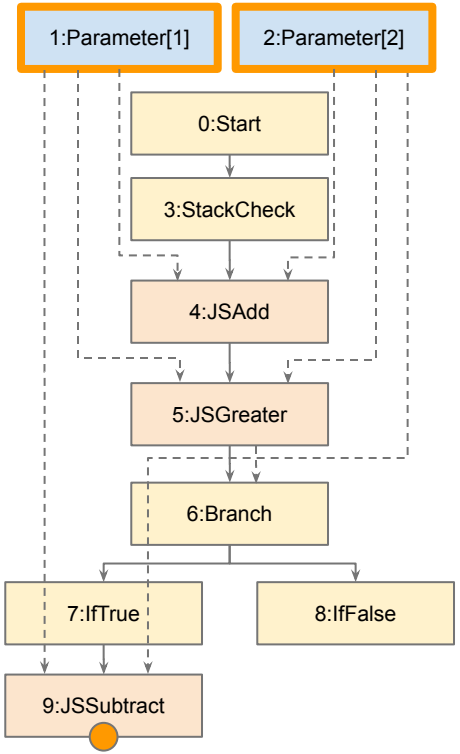

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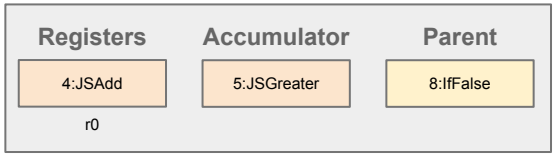
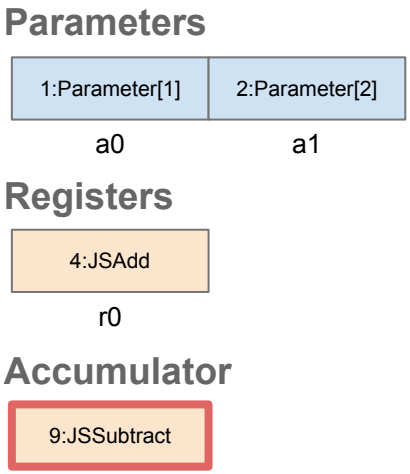
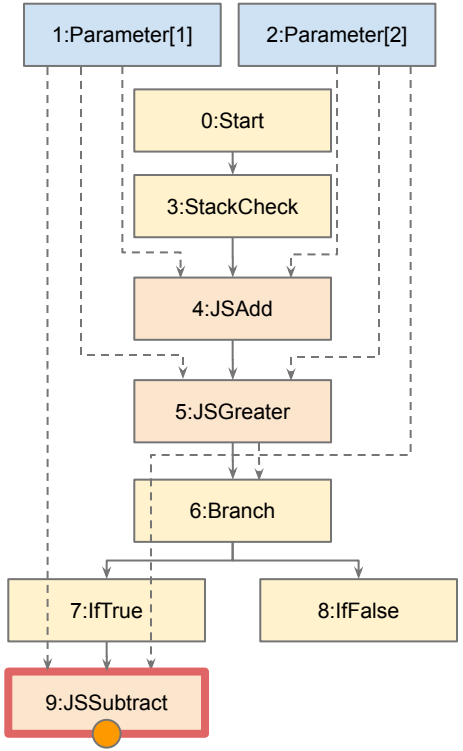
```

22:







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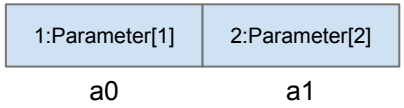
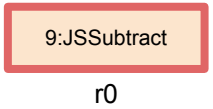
```

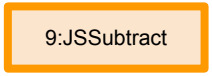
Parameters

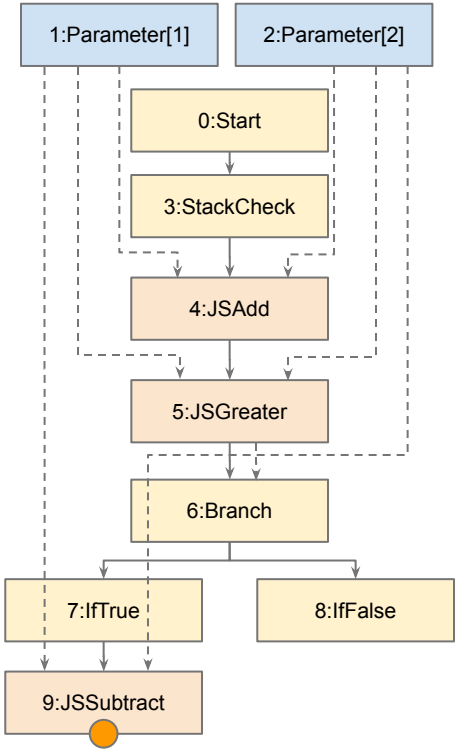


Registers

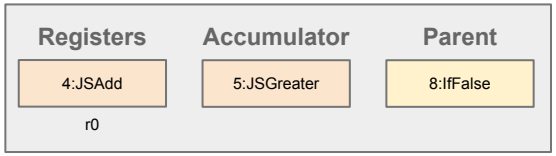


Accumulator





22:



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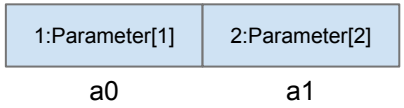
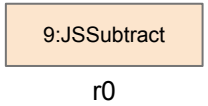
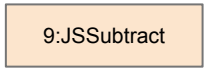
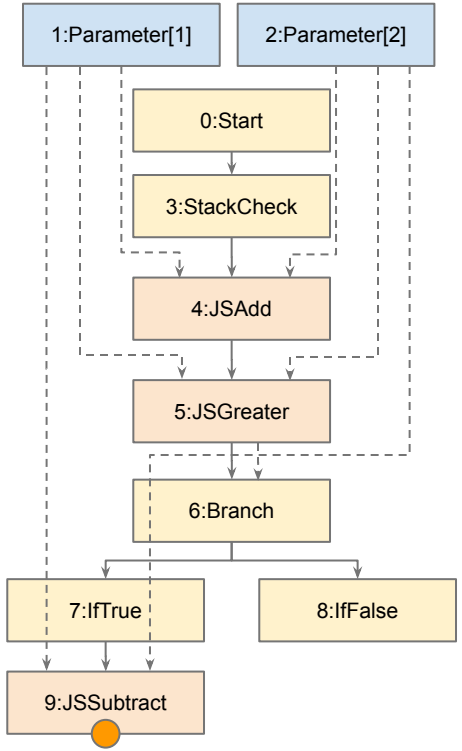


Registers



Accumulator





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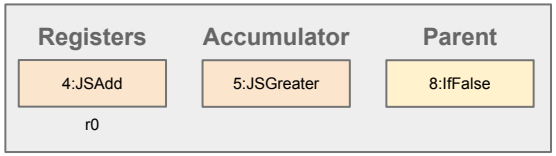

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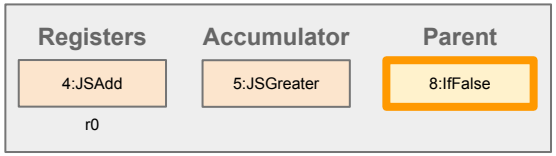
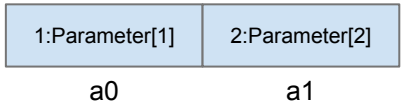
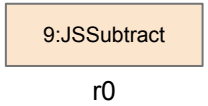


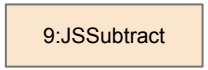
Parameters

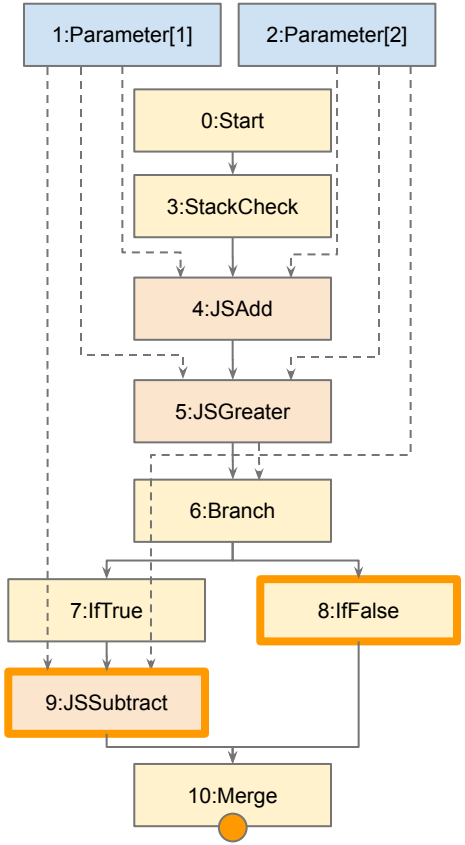


Registers



Accumulator





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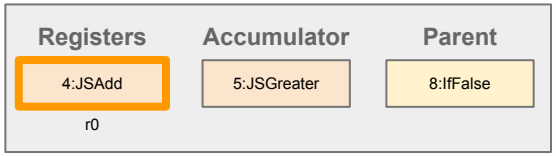

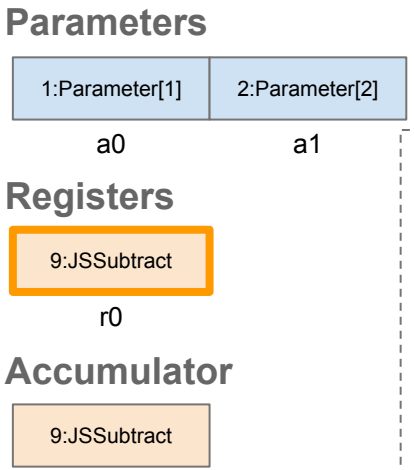

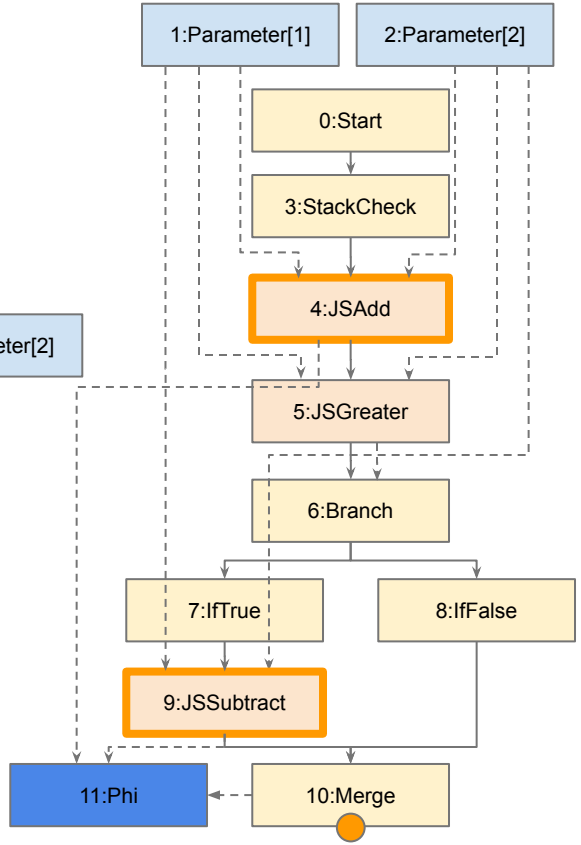

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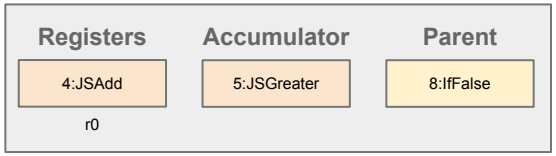

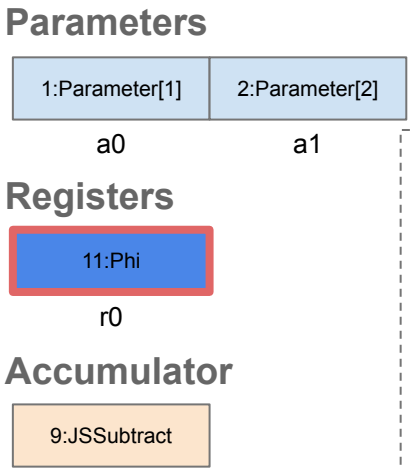

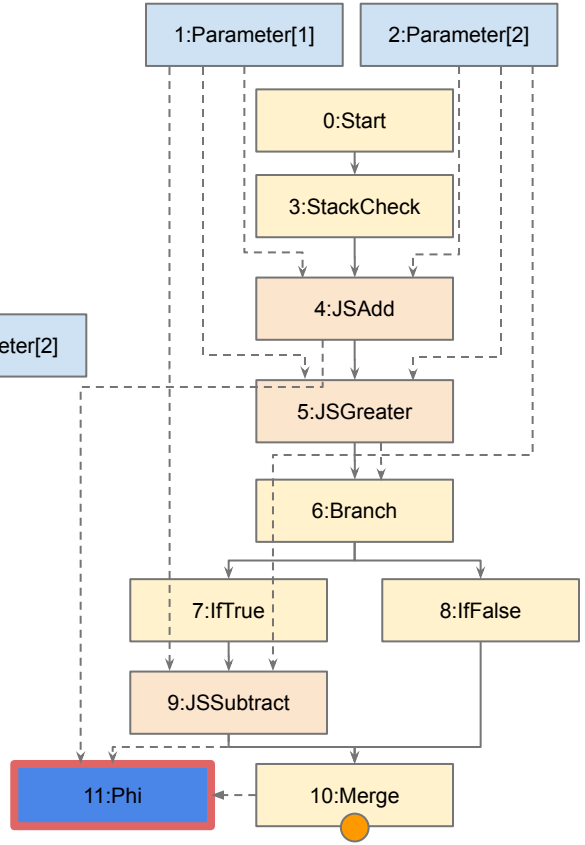

Building a graph

```
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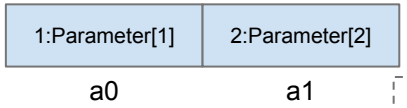
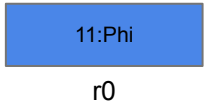
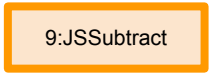
Parameters



Registers



Accumulator



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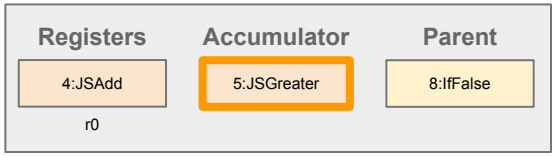

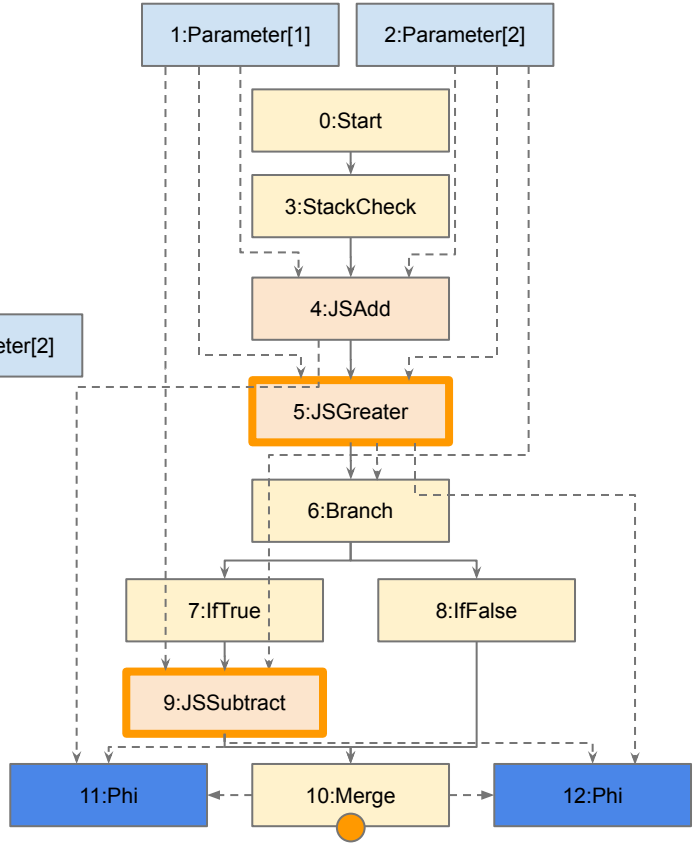

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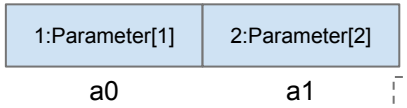

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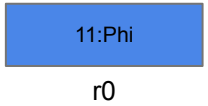

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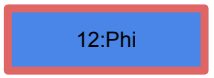

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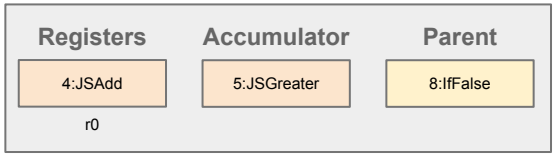

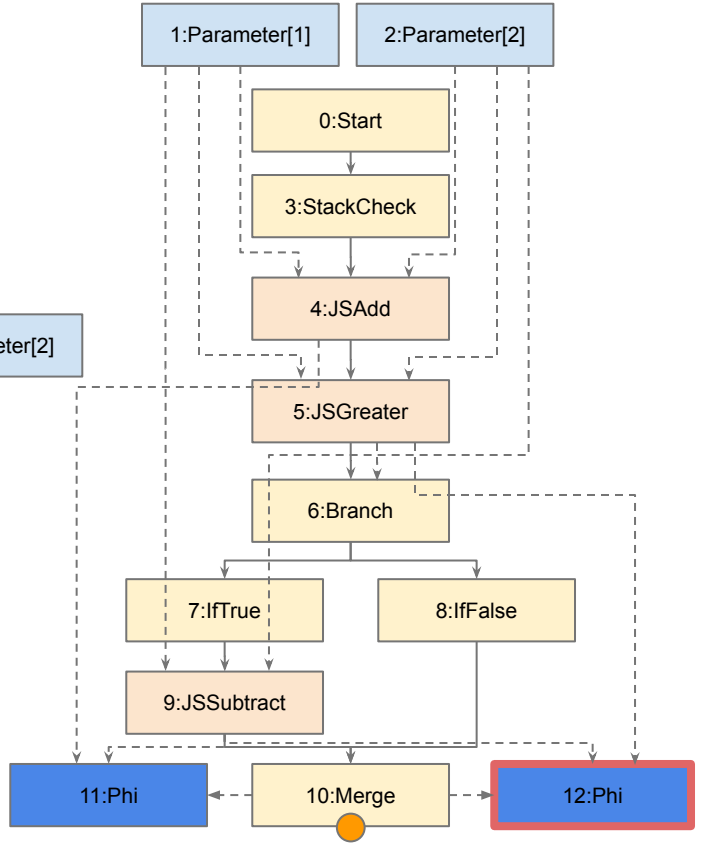

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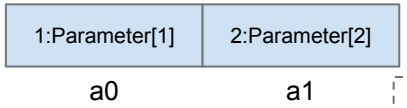

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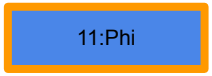

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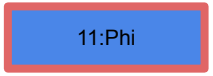

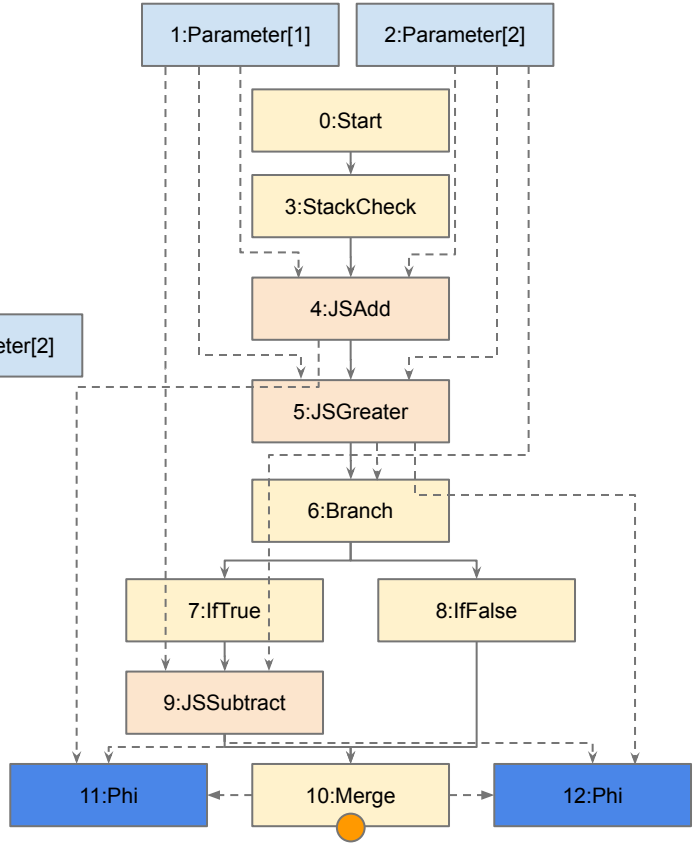

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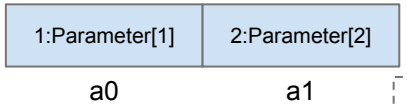

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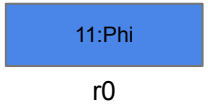
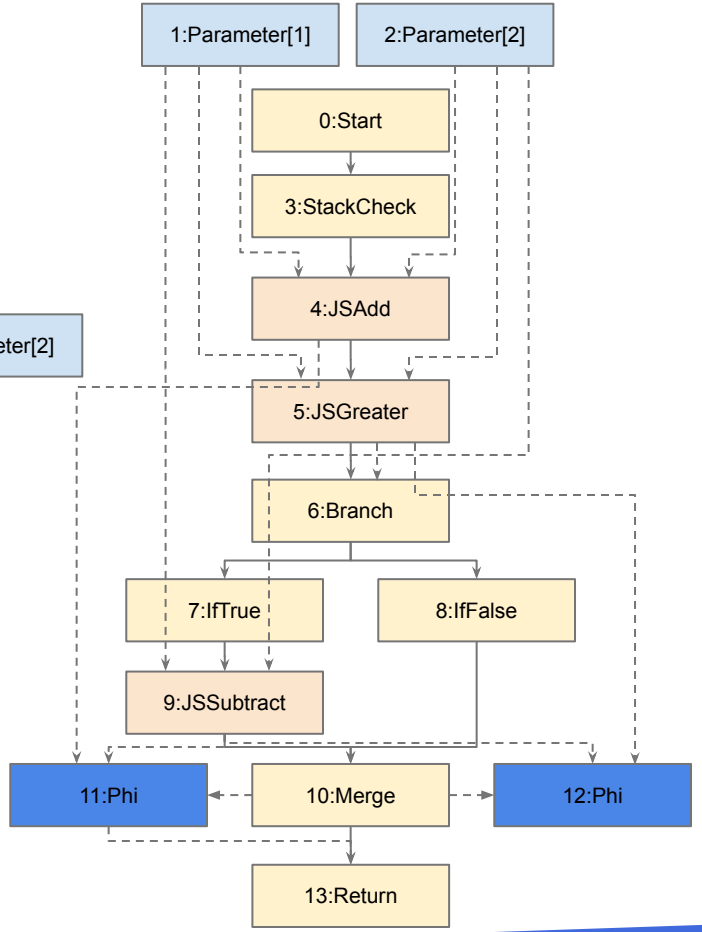


Accumulator



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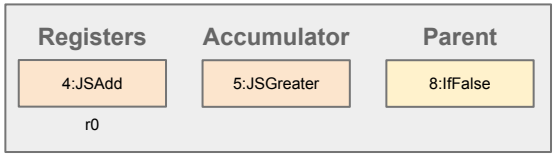

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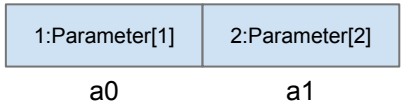

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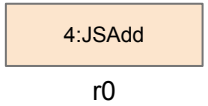

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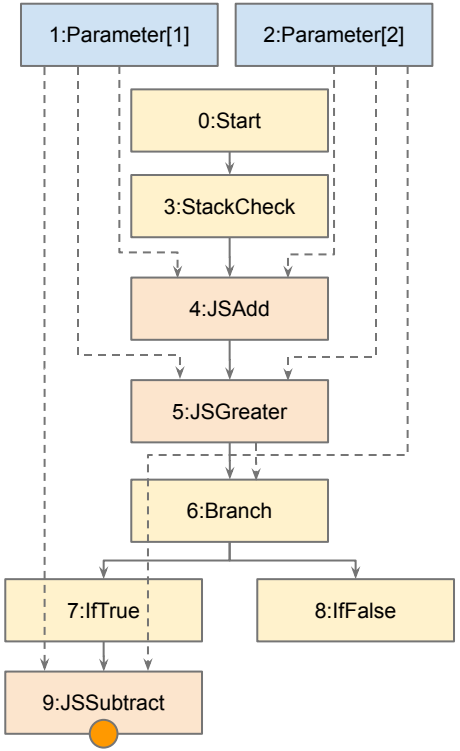

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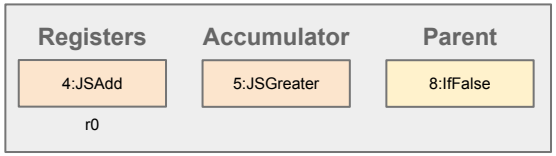

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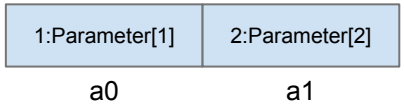

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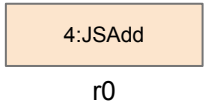

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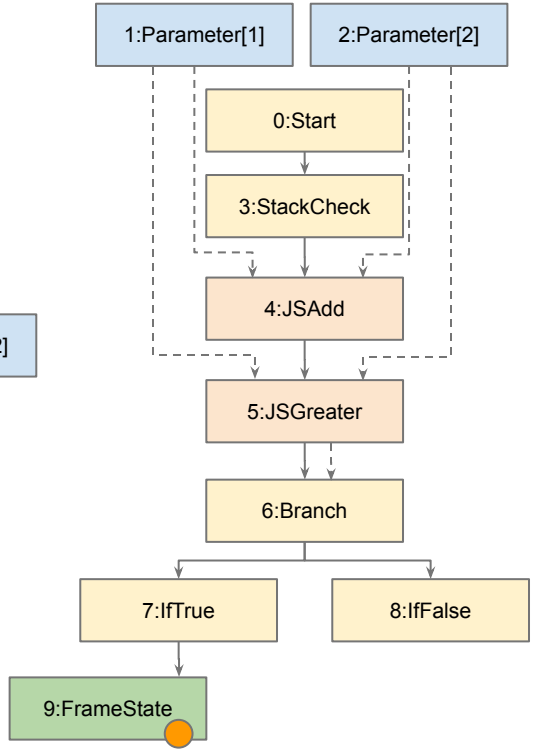

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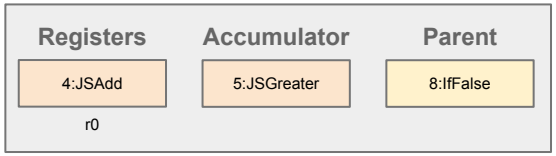

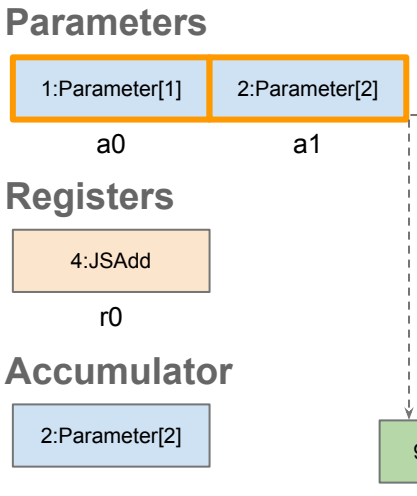

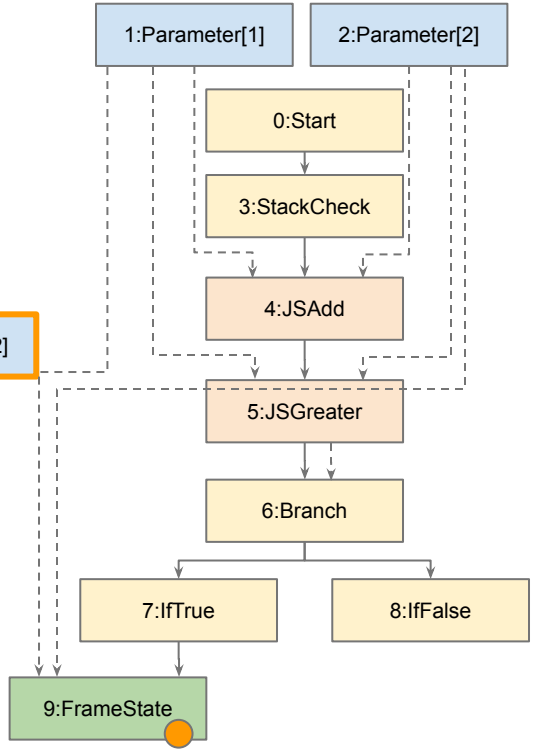

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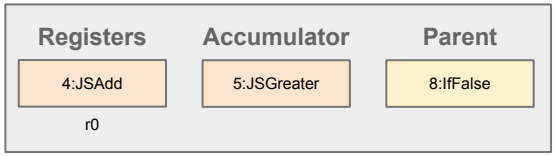

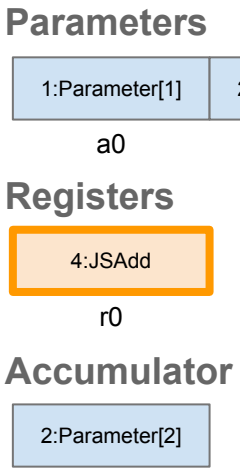

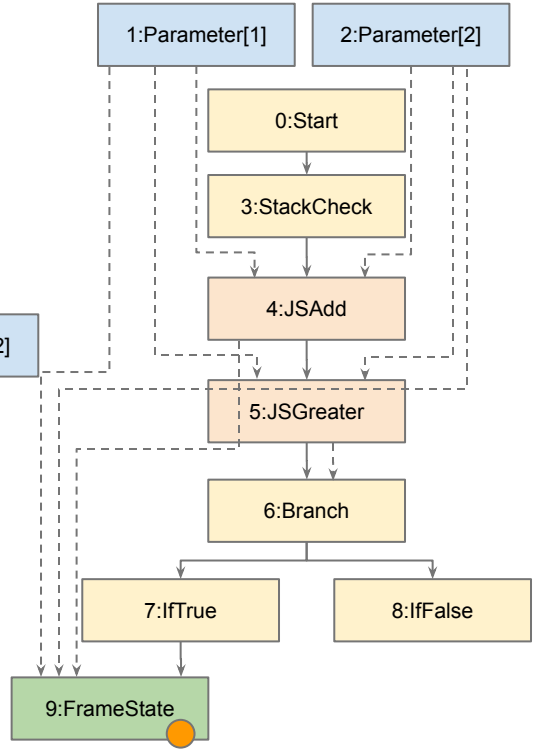

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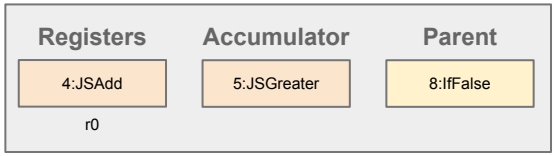

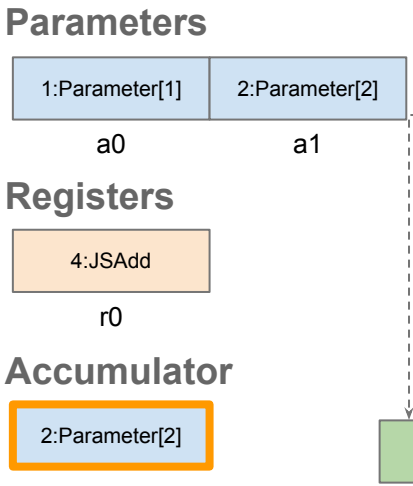

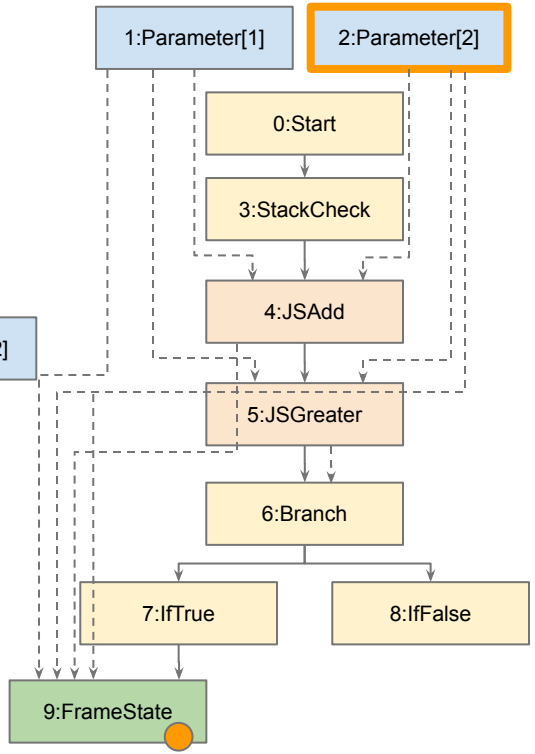

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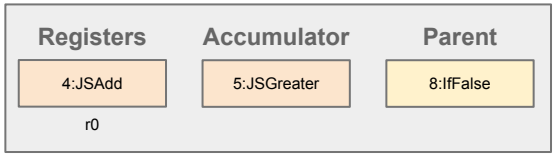

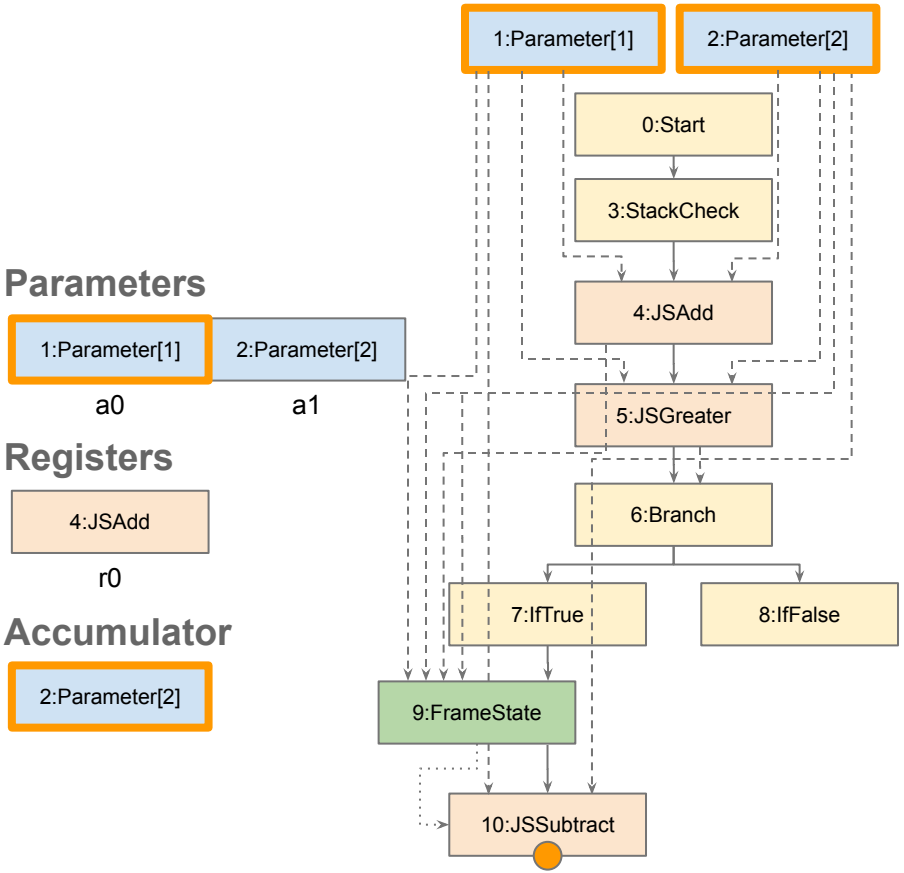

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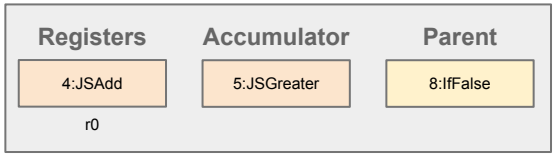

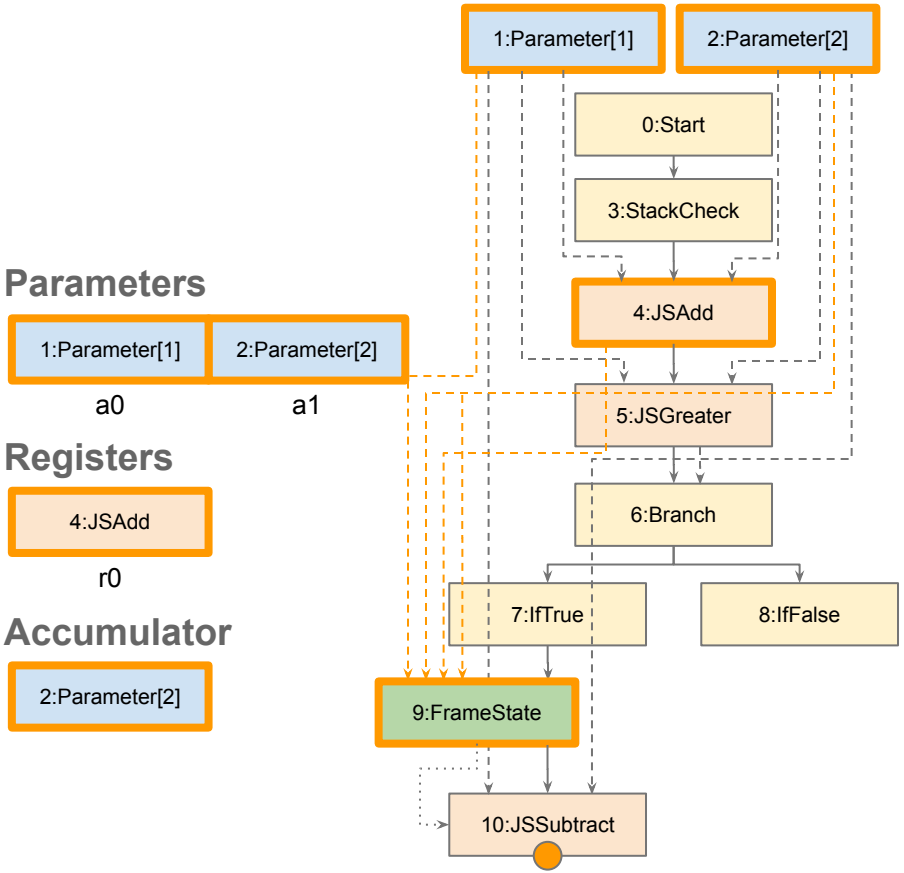

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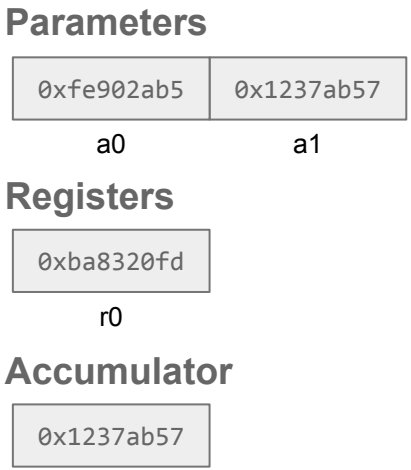

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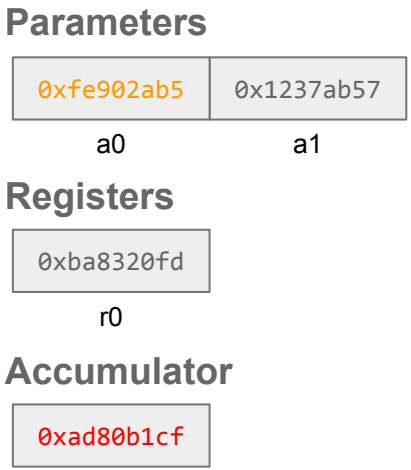
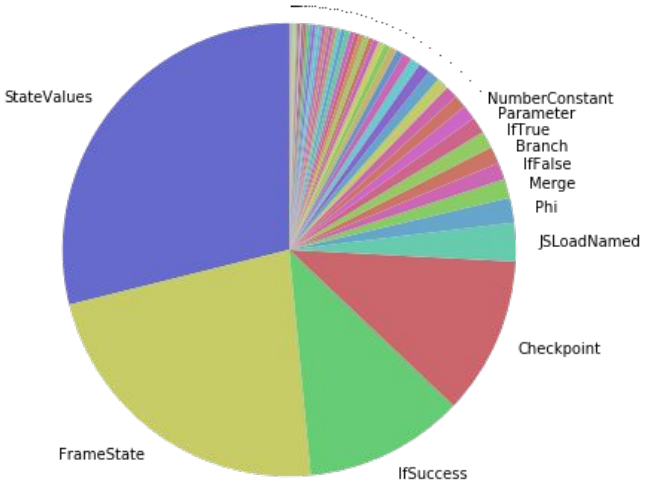


Bytecode Restrictions to Simplifying Graph Creation

- Always deopt to a bytecode
- Well-scoped basic blocks
  - Exception handlers cover a single linear range of bytecode
- No irreducible control flow
- Single backwards-branch to loop header
- Registers in loop-closed form

Static analysis of bytecode

- Pre-analyze bytecode before building graph
  - Liveness analysis (for deoptimisation frame states)
  - Loop assignment analysis (for loop phis)
- Don’t generate unnecessary nodes
  - Avoid memory overhead (40+ bytes per node)
  - Avoid graph traversals



Liveness analysis

- Previously iterated traversal over basic blocks
  - Create liveness maps and state value nodes during graph building
  - Re-create state value nodes based on liveness afterward
- Now iterated passes over bytecode array
  - State value nodes created only once

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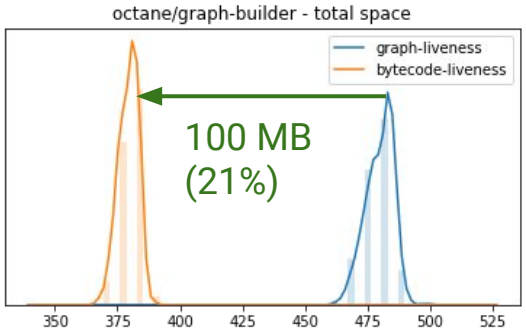

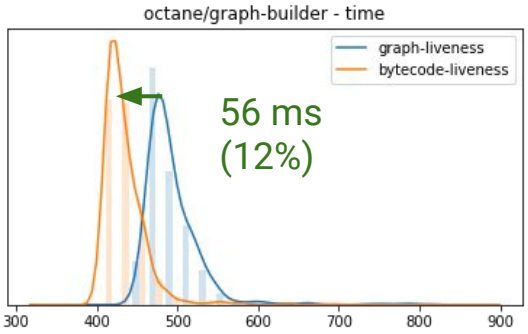

Liveness analysis

- Previously iterated traversal over basic blocks
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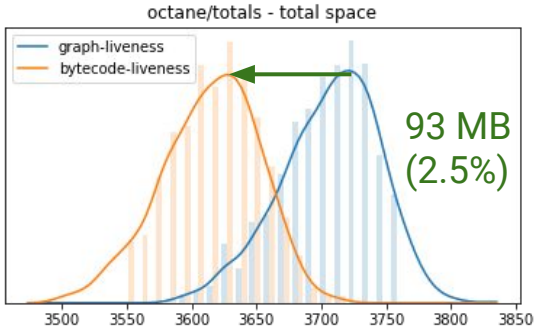

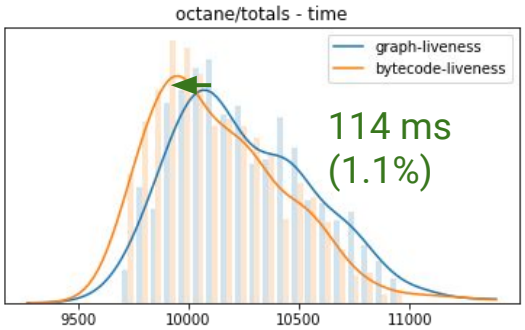

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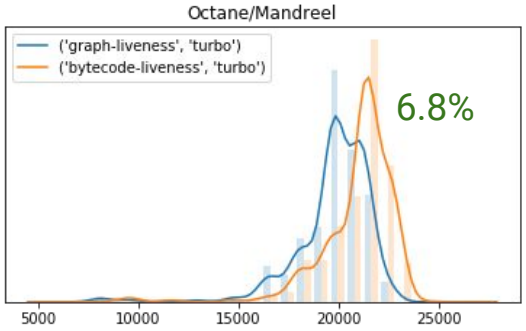
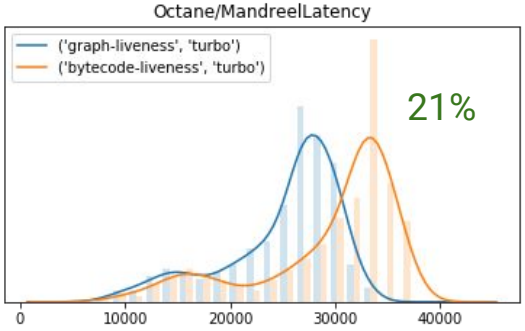




Burning away complex control (Generators)

- Javascript Generators can `yield` expressions at arbitrary points
  - Can introduce irreducible control flow
  - Solution: transform into switch statements on hidden token in prologue and loop headers
  - Result: Turbofan doesn’t need to know anything about generator control flow

Burning away complex control (Generators)

```
function* f() {
    var i = 0;
    while (true) {
        yield i++;
    }
}
```

```
function f(hidden_token) {
    switch(hidden_token)
        case %normal%: break;
        case %resume%: goto loop;
    var i = 0;
    loop:
        switch(hidden_token)
            case %normal%: break;
            case %resume%: goto resume;
        hidden_token = %resume%;
        return i++;
    resume:
        hidden_token = %normal%;
        goto loop;
}
```

Burning away complex control (`try-finally`)

- `try-finally` exception handlers
  - Exit differently depending on what triggered the finally block (fall-through, return or throw)
  - Solution: switch statement at end of finally block
  - Result: Turbofan doesn't need to know anything about `try-finally` control flow

Burning away complex control (`try-finally`)

```
try {
    if a() return;
} finally {
    b();
}
```

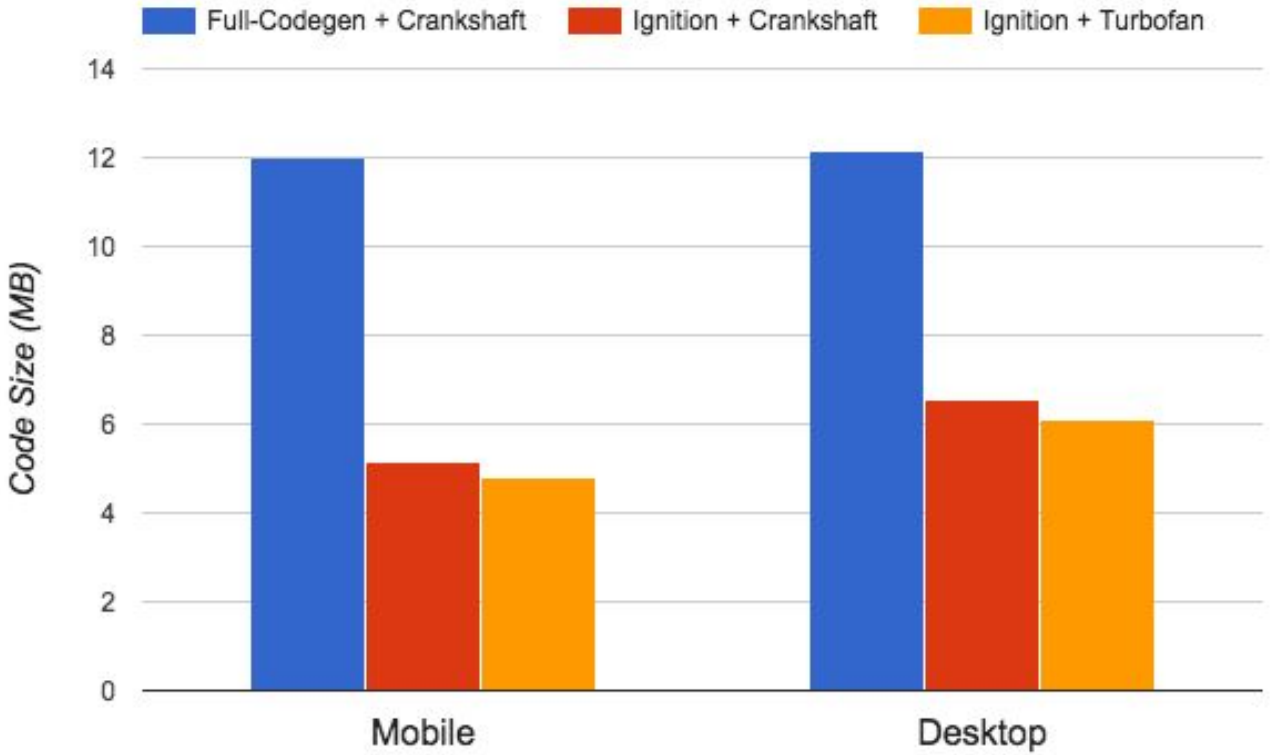
```
try:
    if a() {
        finally_token = %return%;
        goto finally;
    }
    finally_token = %fallthrough%;
    goto finally;

throw_handler:
    finally_token = %throw%;

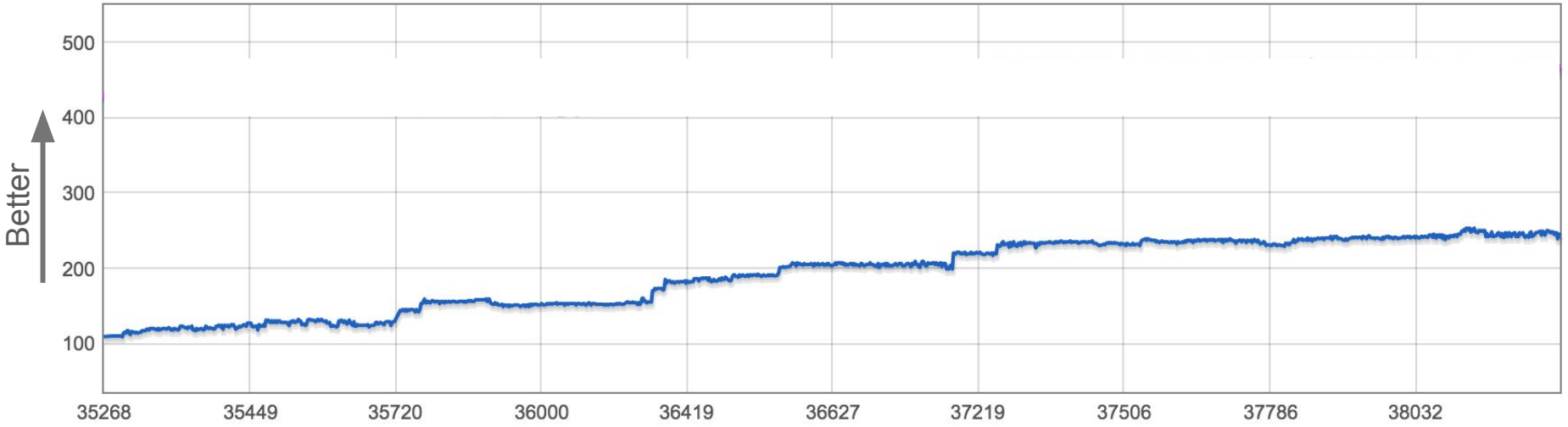
finally:
    b();
    switch(finally_token)
        case %return%: return;
        case %throw%: rethrow();
        case %fallthrough%: break;
```

Performance Results

Code Memory Usage (Real Websites)



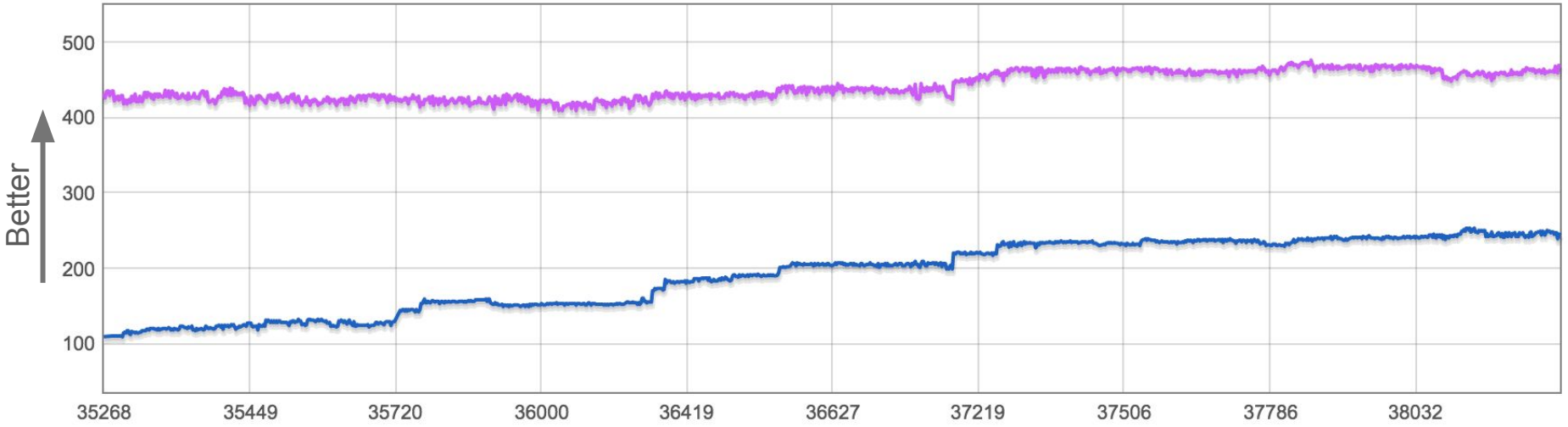
Ignition vs Full-Codegen



Octane (Nexus 5)

Crankshaft and TurboFan disabled

Ignition vs Full-Codegen



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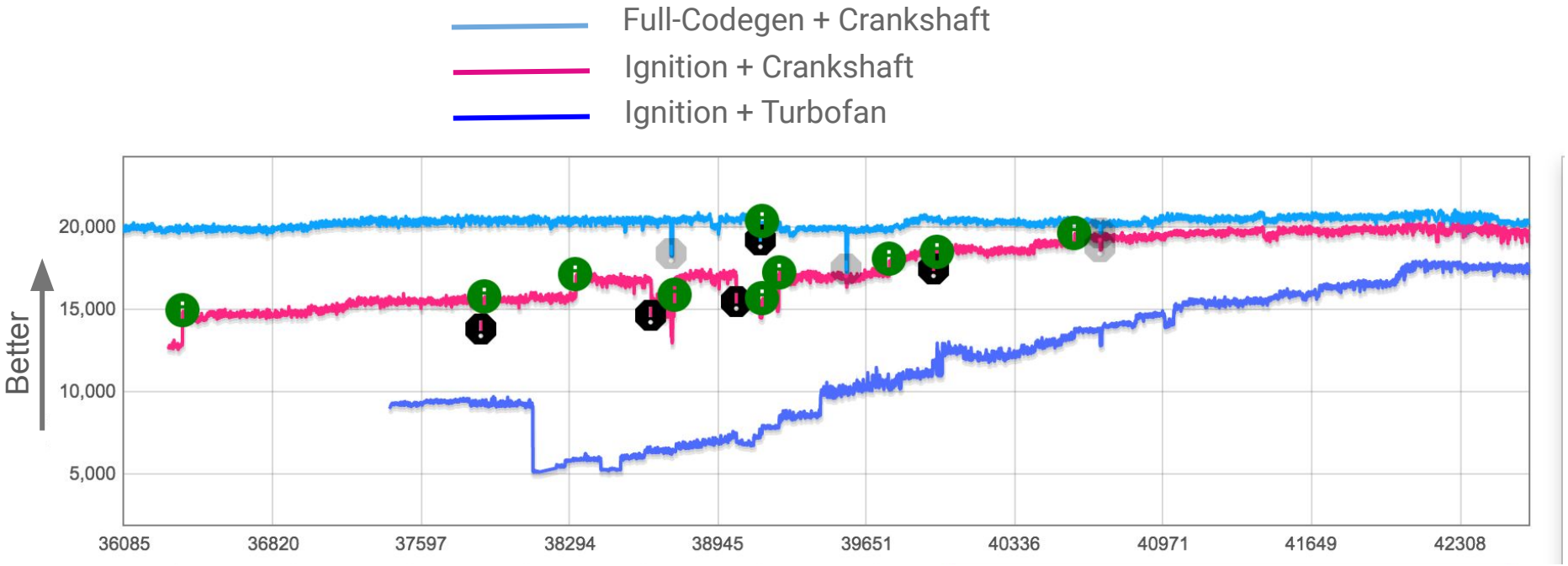
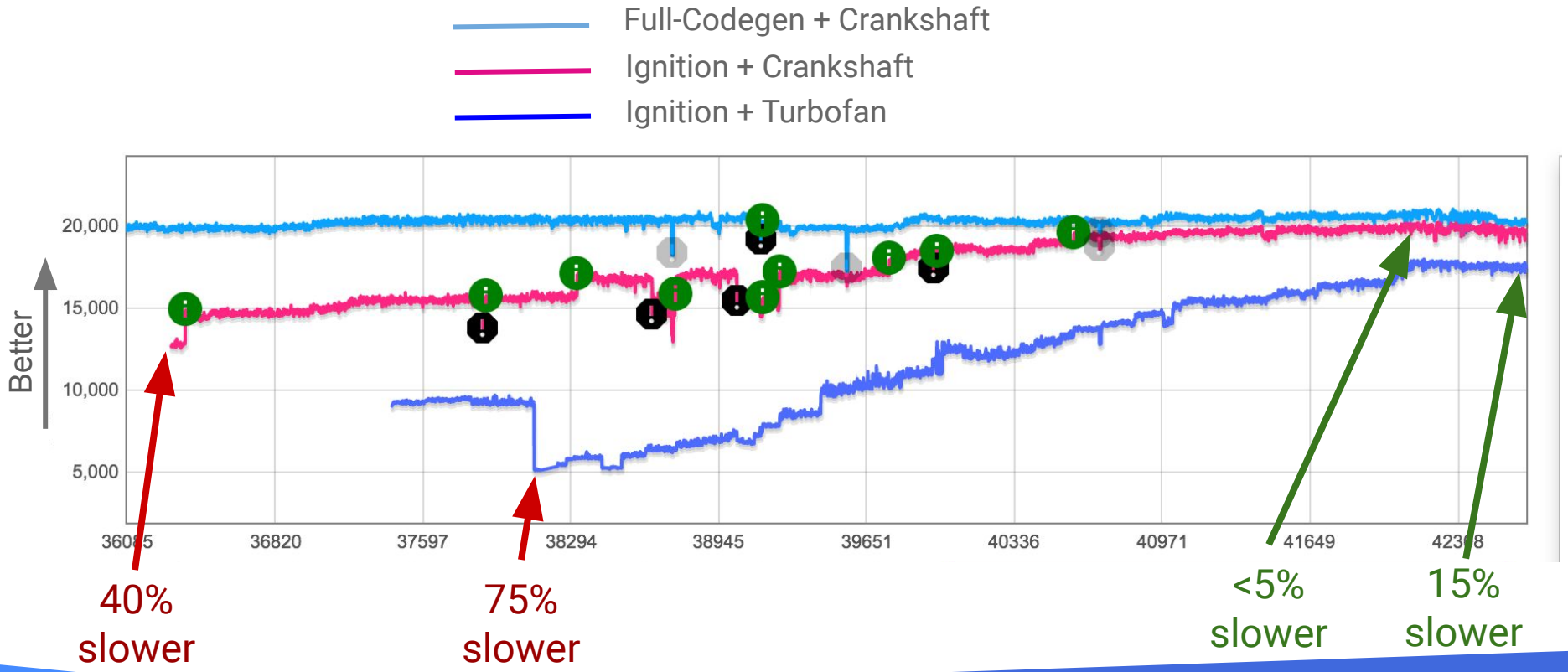
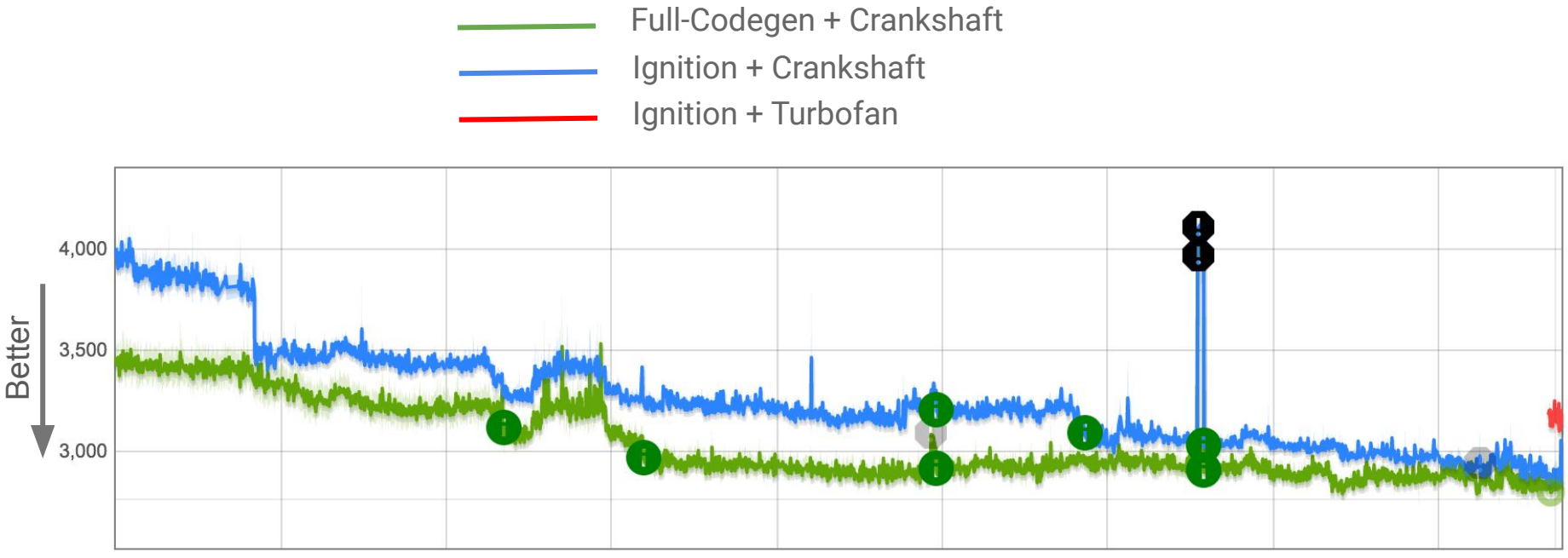
Octane Performance



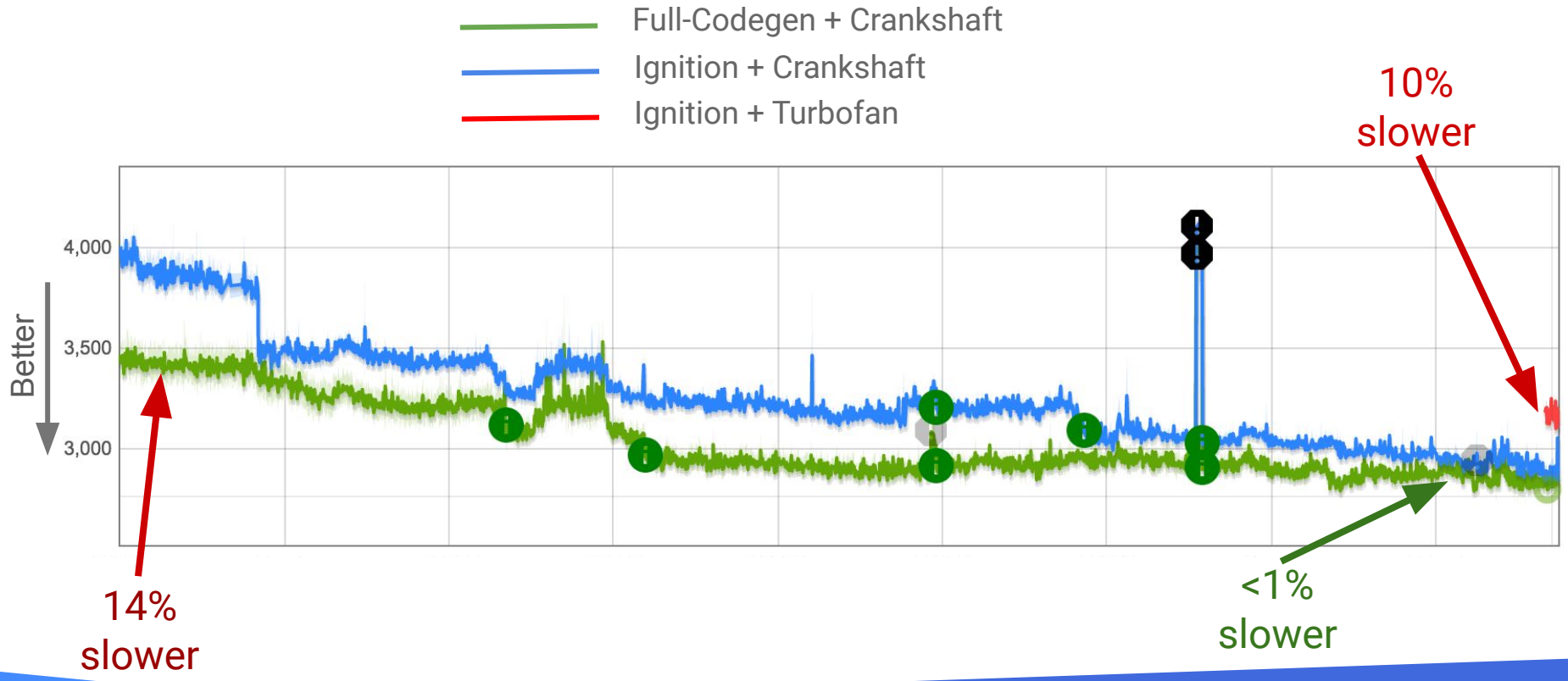
Octane Performance



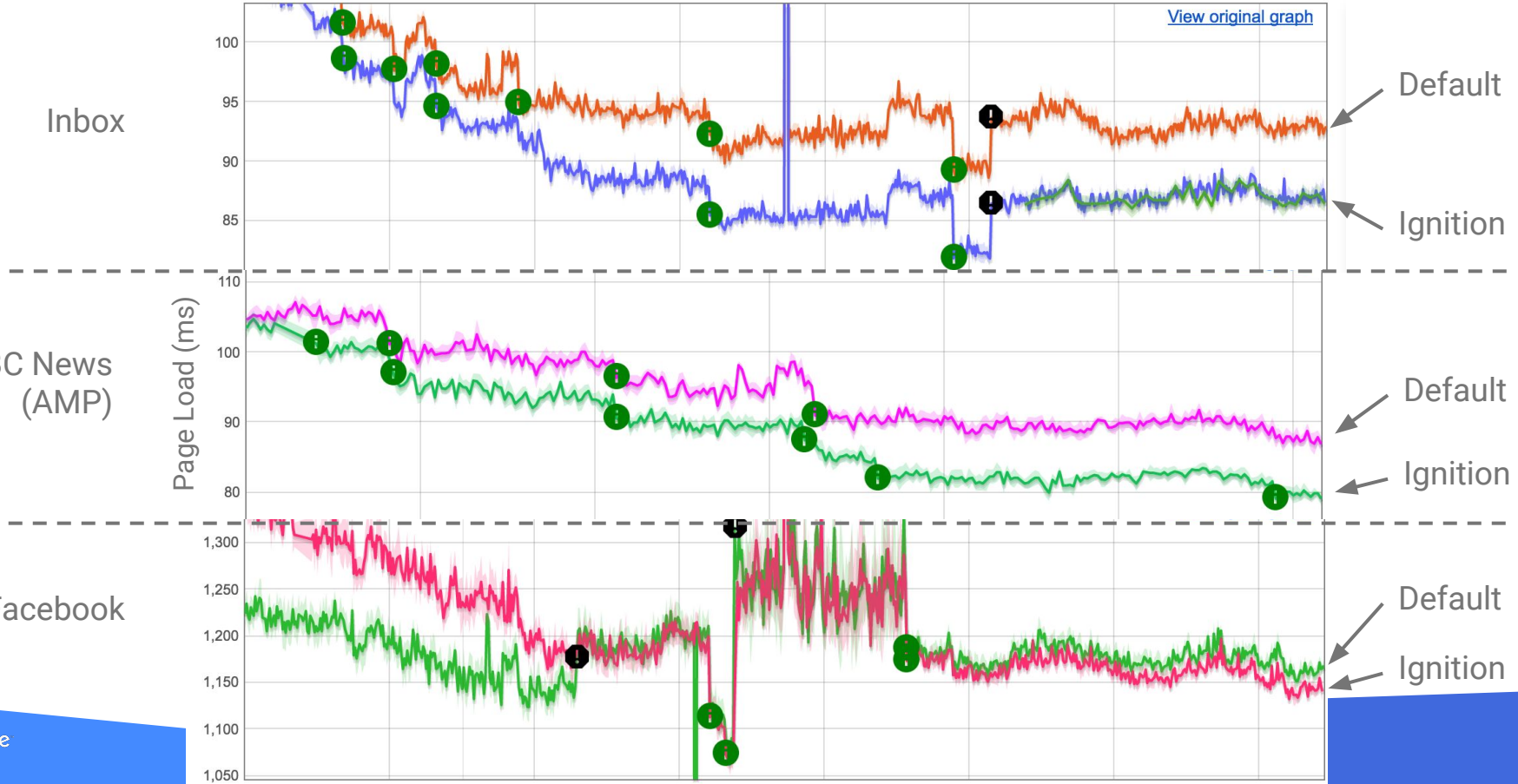
Speedometer Performance



Speedometer Performance

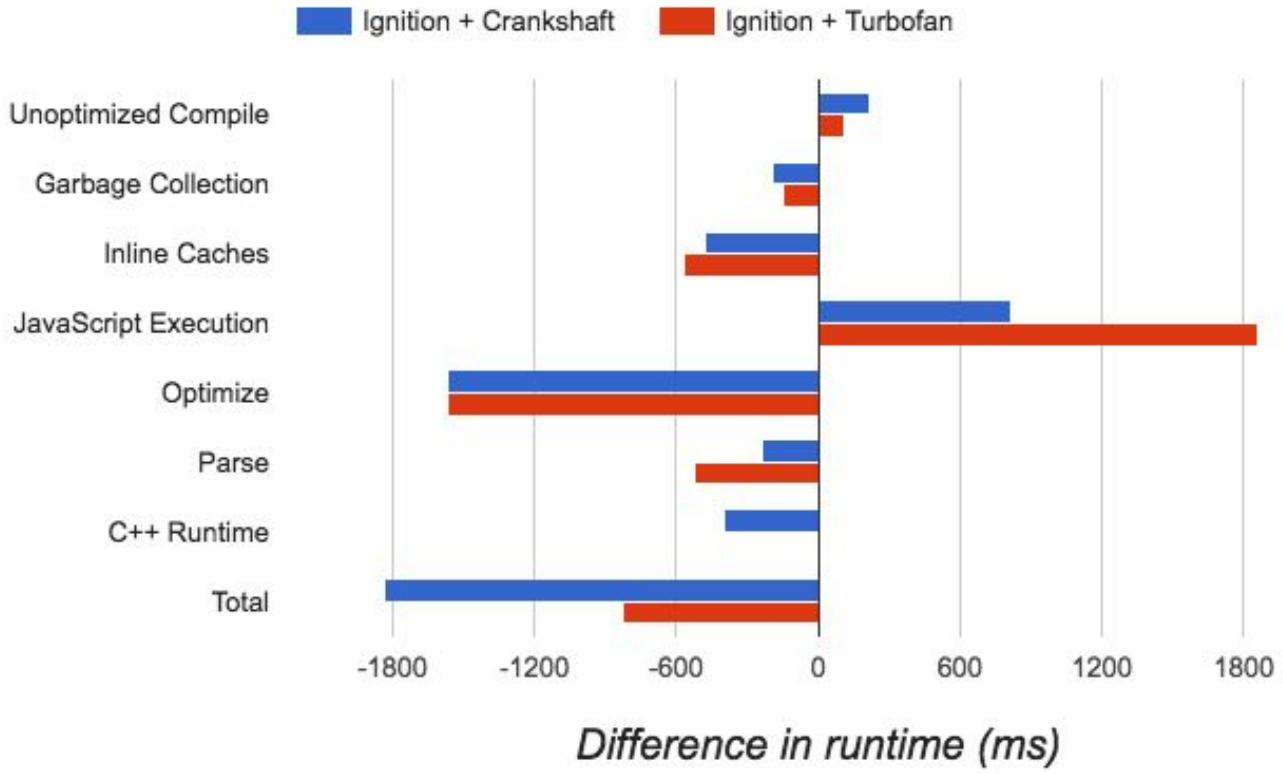


Startup Time (Real Websites)



Startup Time (Real Websites)

Where time is spent (Real Websites)



Summary

- Ignition + Turbofan is the future of V8
- Restrictions on bytecode can simplify optimized graph creation
- Optimizing for real-world exposes different trade-offs