CS 252:

Advanced Programming Language Principles

Virtual Machines and JITs

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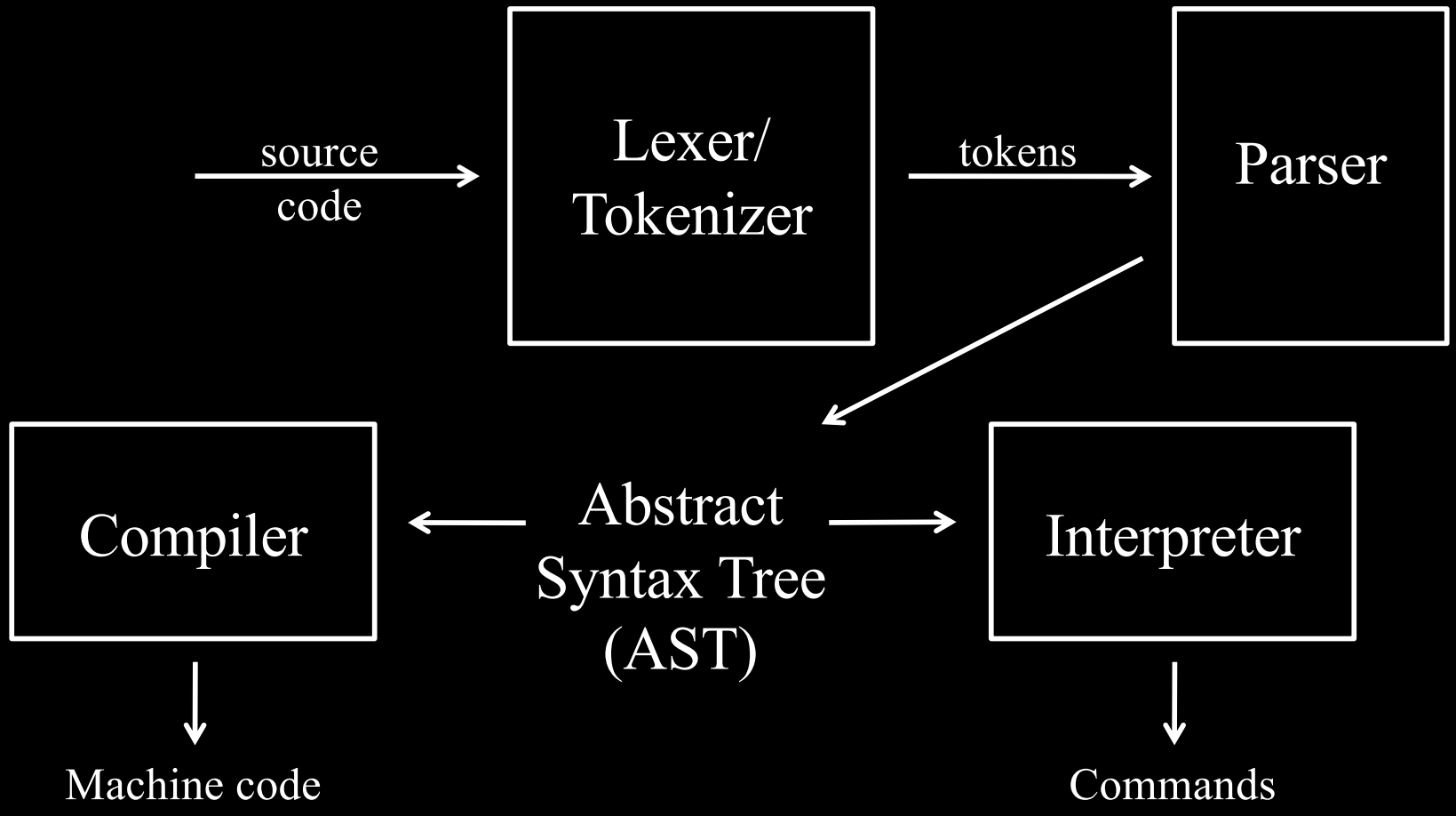
A Review of Compilers



Virtual Machines (VM)

- Code is compiled to *bytecode*
  - low-level
  - platform independent
- The VM interprets bytecode

Lab: Scheme VM

In today's lab, you will implement:

- a compiler for Scheme
- a stack-based VM

Input program

```
(println (+ 2 3 4))
(println (- 13 (* 2 4)))
(println (- 10 4 3))
```

Supported VM Operations

- **PUSH** – adds argument to stack
- **PRINT** – pops & prints top of stack
- **ADD**
  - pops top two elements
  - adds them together
  - places result on stack
- **SUB** – subtraction
- **MUL** – multiplication

Bytecode Output

```
PUSH 2
PUSH 3
ADD
PUSH 4
ADD
PRINT
PUSH 13
PUSH 2
PUSH 4
MUL
SUB
PRINT
PUSH 10
PUSH 4
SUB
PUSH 3
SUB
PRINT
```

Lab, part 1: Write a VM

- Starter code is provided.
- `PUSH` and `PRINT` are functional.
- Your job: add support for the other opcodes

Compiler or Interpreter?

- Compilers
  - –efficient code
- Interpreters
  - –runtime flexibility
- Can we get the best of both?

Review of compiler.rb
(in class)

Just-in-time compilers (JITs)

- interpret code
- "hot" sections are compiled *at run time*

JIT tradeoffs

+ Speed of compiled code
+ Flexibility of interpreter
− Overhead of both approaches
− Complex implementation

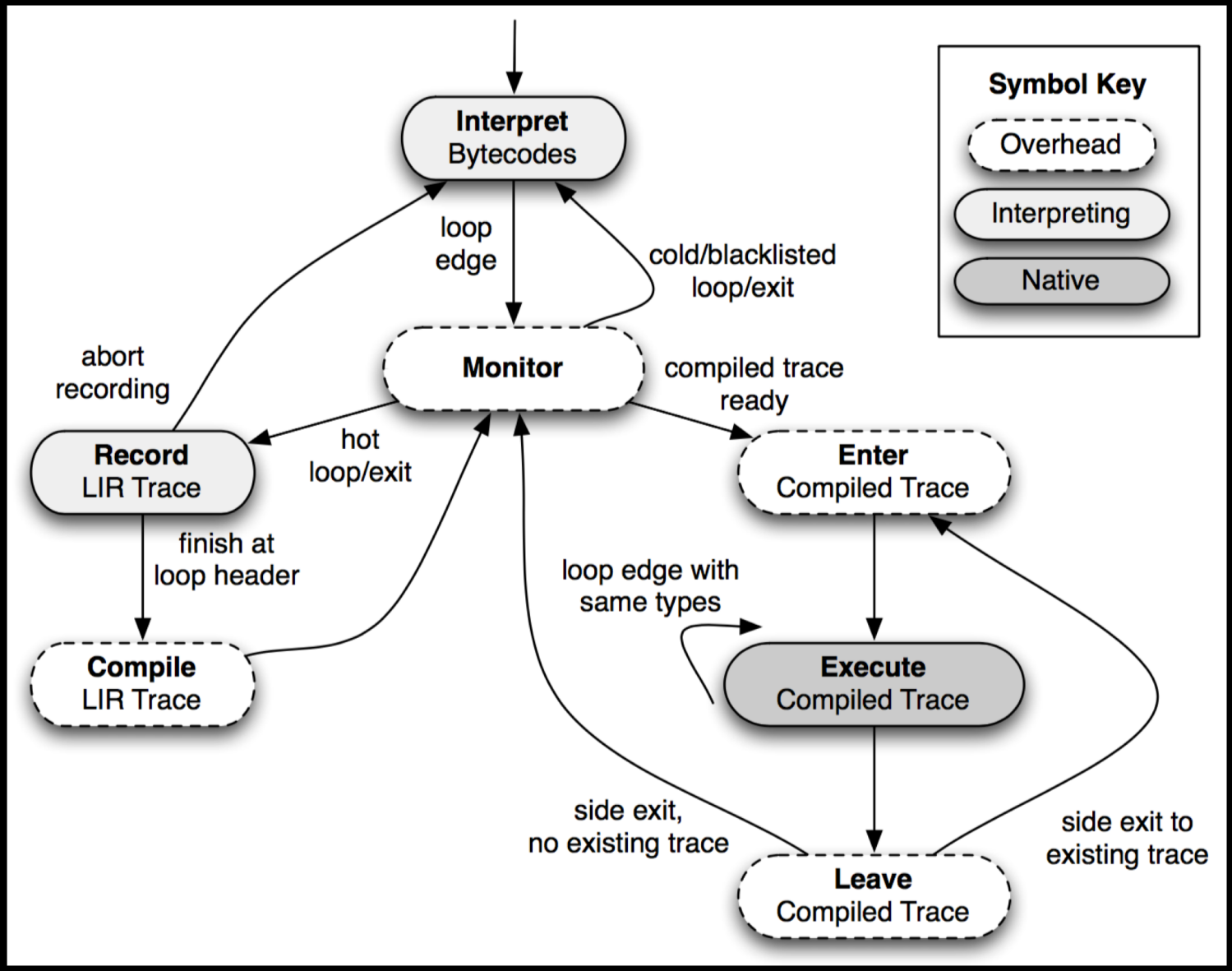
Dynamic recompilation

- JIT pursues aggressive optimizations
  - make assumptions about code
  - guard conditions verify assumptions
- Unexpected cases interpreted
- Can outperform static compilation

Types of JITs

- Method based
  - –Compiles methods
- Trace based
  - –Compiles loops
  - –Gal et al. 2009
    http://www.stanford.edu/class/cs343/resources/tracemonkey.pdf

Trace-based JIT design (Gal et al. 2009)



How can a language designer make use of a JIT?

1. Become an expert in JITs
   - study the latest techniques
   - build large code bases to test
   - profile your code execution
2. Use someone else's JIT-ed VM

Lab, part 2 – Write a Compiler

- Starter code is provided.
- `println` is functional.
- Your job: update `to_bytecode` to add support for the mathematical operators.

EXTRA CREDIT

Add compiler support for

- if expressions
- boolean variables
- let expressions

Add VM support for

- labels
- Jump (`JMP`/`JZ`/`JNZ`) operations
- `STOR`/`LOAD` operations

SUPER EXTRA CREDIT

- If you did the extra credit, try to implement a JIT
  - Use the `evaluate` method normally
  - When a "hot" code section is detected, produce bytecode
  - Future executions of that code section should use the opcodes