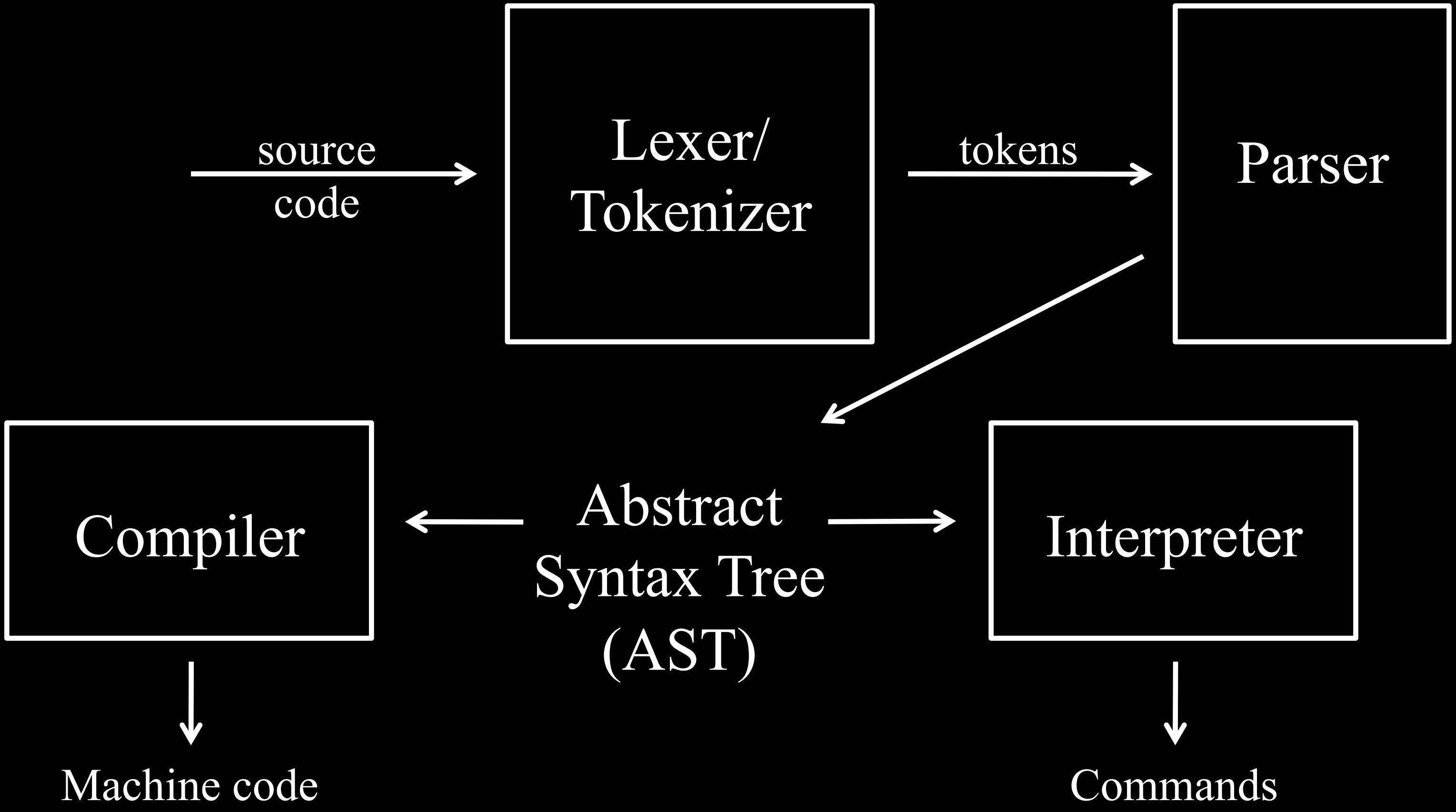
CS 252:
Advanced Programming Language Principles

Virtual Machines and JITs

Prof. Tom Austin
San José State University

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 – Write a Compiler and a VM

- Starter code is provided.
- `println` is functional.
- Your job: 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

Compiler or Interpreter?

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

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

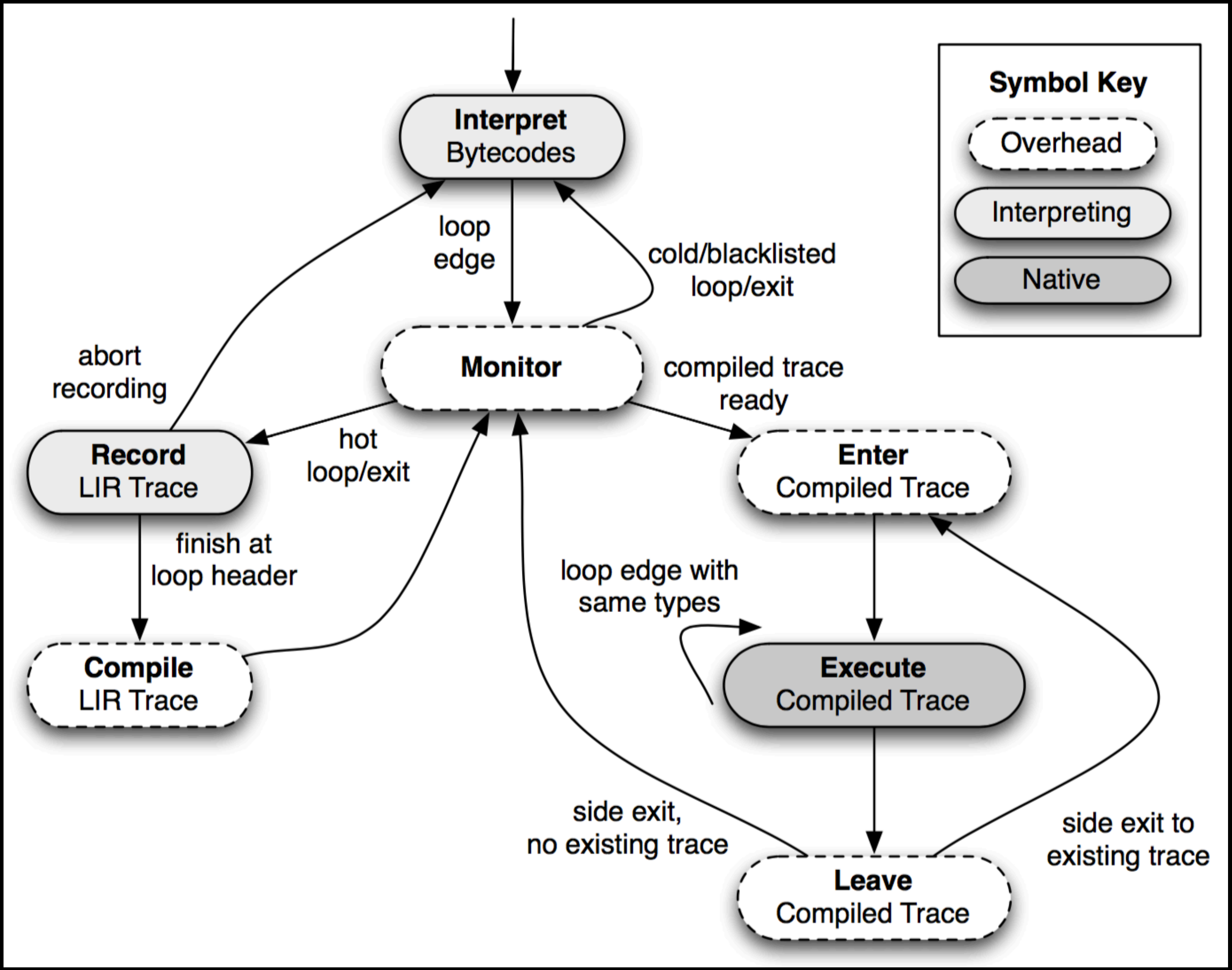
Dynamic recompilation

- 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

"That's all Folks!"