COS320: Compiling Techniques

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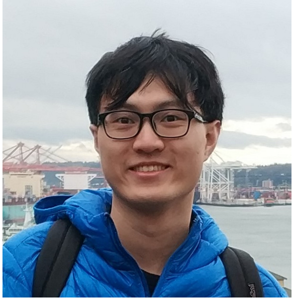
Welcome!

- **Instructor**: Zak Kincaid
- **TAs**:

Chirag Bharadwaj



Qinshi Wang

- **Website**: `http://www.cs.princeton.edu/courses/archive/spring19/cos320/`
- **Piazza**: `https://piazza.com/princeton/spring2019/cos320`
- **Office hours**: see website

What is a compiler?

- A **compiler** is a program that takes a program written in a *source language* and translates it into a functionally equivalent program in a *target language*.
  - Source languages: C, Java, OCaml, …
  - Target languages: x86 Assembly, Java bytecode, C, …

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    - Target languages: x86 Assembly, Java bytecode, C, …
- A compiler can also
    - Report errors & potential problems
        - Uninitialized variables, type errors, …
    - Improve (“optimize”) the program

Why take COS320?

You will learn:

- **How high-level languages are translated to machine language**
- How to be a better programmer
  - What can a compiler do?
  - What can a compiler *not* do?
- Lexing & Parsing
- (Some) functional programming in OCaml
- A bit of programming language theory
- A bit of computer architecture

Course resources

- Recommended textbook: *Modern compiler implementation in ML* (Appel)
- Real World OCaml (Minsky, Madhavapeddy, Hickey)
  `realworldocaml.org`

Grading

- 60% Homework
  - 6 assignments, evenly weighted
  - HW1: OCaml introduction
  - HW2: Build an x86 simulator
  - HW3-6: Build a compiler
- 20% Midterm
  - March 14, in class
- 20% Final

Homework policies

- Except for HW1, homework can be done individually or in pairs
- Late assignments will be penalized 1% per hour past the deadline.
- Five late passes, can submit up to 24 hours late without penalty (at most 3/HW).

Feel free to discuss with others at **conceptual** level.
Submitted work should be your own.

Lecture expectations

- Lecture 1: Intro
- Lecture 2: OCaml (review COS326)
- Lecture 3: x86 (review COS217)
- Lecture $4 + k$: not review

Compilers

(Programming) language = syntax + semantics

- **Syntax**: what sequences of characters are valid programs?
  - Typically specified by context-free grammar

```
<expr> ::=<integer>
         |<variable>
         |<expr> + <expr>
         |<expr> * <expr>
         |(<expr>)
```

- **Semantics**: what is the behavior of a valid program?
  - *Operational semantics*: how can we execute a program?
    - In essence: an interpreter
  - *Axiomatic semantics*: what can we prove about a program?
  - *Denotational semantics*: what mathematical function does the program compute?

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The job of a compiler is to translate from the syntax of one language to another, but preserve the semantics.

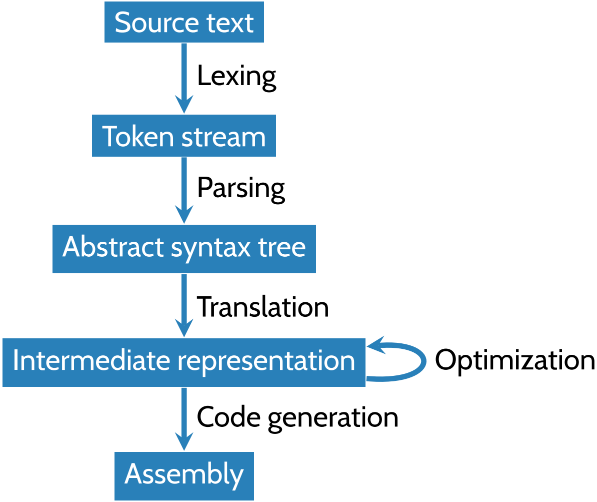
```
#include <stdio.h>

int factorial(int n) {
  int acc = 1;
  while (n > 0) {
    acc = acc * n;
    n = n - 1;
  }
  return acc;
}

int main(int argc, char *argv[]) {
  printf(”factorial(6)␣=␣%d\n”, factorial(6));
}
```

```
_factorial:
## BB#0:
        pushl   %ebp
        movl    %esp, %ebp
        subl    $8, %esp
        movl    8(%ebp), %eax
        movl    %eax, -4(%ebp)
        movl    $1, -8(%ebp)
LBB0_1:
        cmpl    $0, -4(%ebp)
        jle     LBB0_3
## BB#2:
        movl    -8(%ebp), %eax
        imull   -4(%ebp), %eax
        movl    %eax, -8(%ebp)
        movl    -4(%ebp), %eax
        subl    $1, %eax
        movl    %eax, -4(%ebp)
        jmp     LBB0_1
LBB0_3:
        movl    -8(%ebp), %eax
        addl    $8, %esp
        popl    %ebp
        retl
```

Compiler phases (simplified)



COS320 assignments

By the end of the course, you will build (in OCaml) a complete compiler from a high-level type-safe language (“Oat”) to a subset of x86 assembly.

- HW1: OCaml programming
- HW2: X86lite interpreter
- HW3: LLVMlite compiler
- HW4: Lexing, Parsing, simple compilation
- HW5: Higher-level Features
- HW6: Analysis and Optimizations

We will use the assignments from Penn’s CIS 354, provided by Steve Zdancevic.

OCaml

- Why OCaml?
    - Algebraic data types + pattern matching are *very* convenient features for writing compilers
- OCaml is a *functional* programming language
    - *Imperative* languages operate by mutating data
    - *Functional* languages operate by producing new data
- OCaml is a *typed* language
    - Contracts on the values produced and consumed by each expression
    - Types are (for the most part) *automatically inferred*.
        - Good style to write types for top-level definitions

Preparation

- Excellent preparation: COS326 (Functional programming)
  - More than you will need for this class.
- Thursday’s lecture + review sessions
  - Poll on Piazza

HW1: Hellocaml

- Available **now** on the course website
  - Topic: OCaml introduction + interpreter & compiler for a little calculator language
- OCaml dev environment on VirtualBox virtual machine
  - Recommend Emacs + merlin