COS320: Compiling Techniques

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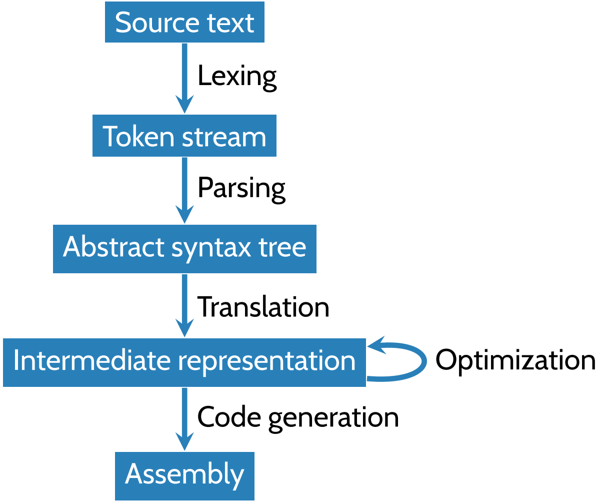
- Reminder: HW1 due on Tuesday
- **Office hour change**: Qinshi's office hours will start at **3pm** on Thursdays

Compiler phases (simplified)



Syntax-directed translation

- Compilation strategy in which *syntax* of the program drives code generation
  - Assembly code generated from AST, or even directly by the parser
  - No substantial code analysis or transformation
- Example: Lecture 2 compiler

```
x := 6;
ANS := 1;
WhileNZ (x) {
  ans := ans * x;
  x := x - 1
}
```

→

```
let run () =
  let v_X = ref 0 in
  let v_ANS = ref 0 in
  v_X := 6;
  v_ANS := 1;
  while !v_X != 0 do
    v_ANS := (!v_ANS * !v_X);
    v_X := (!v_X + -1)
  done;
  !v_ANS
```

Syntax-directed translation

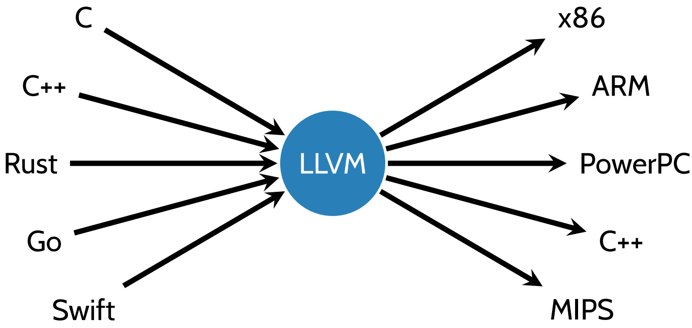
- Compilation strategy in which *syntax* of the program drives code generation
  - Assembly code generated from AST, or even directly by the parser
  - No substantial code analysis or transformation
- Example: Lecture 2 compiler
- Easy to implement, but:
  - produces inefficient code
  - can be difficult to implement some language features (e.g., first-class functions)

Intermediate Representations

Separation of concerns

- An IR breaks code generation up into two phases. Simpler & easier to implement
- Simplifies optimization
  - E.g., in optimization pass, we don't have to think about how code motion interacts w/ register use
- Safety: IR can enforce maintenance of invariants (e.g. types)

Reusability



What makes a good IR?

1. Convenient to translate source language to IR
2. Convenient to generate assembly from IR
3. Convenient to manipulate IR during optimization

Varieties of IR

- In practice, compilers often use *several* IRs
  - GCC: Source $\rightarrow$ GENERIC $\rightarrow$ GIMPLE $\rightarrow$ RTL $\rightarrow$ Target
- **High-level**
  - Preserves high-level structures, but may simplify (e.g., convert `for` to `do/while`) or elaborate
  - Some high-level optimizations (e.g., function inlining)
- **Mid-level**
  - "Abstract assembly language"
    - Still retains some high-level features (e.g., explicit functions, variables, structured data)
  - Machine-independent optimizations
- **Low-level**
  - Machine-dependent optimizations

A simple let-based IR

```
x = 2*(x + y) - (z * z)
```

→

```
let tmp1 = x + y
let tmp2 = 2 * tmp1
let tmp3 = z * z
let tmp4 = tmp2 - tmp3
x = tmp4
```

1. Makes evaluation order explicit (no nested expressions)
2. Names all intermediate values
3. Distinguish between variables & intermediate values
4. Invariant: there is exactly one assignment to any temporary (warm-up to SSA)