COS320: Compiling Techniques

Zak Kincaid

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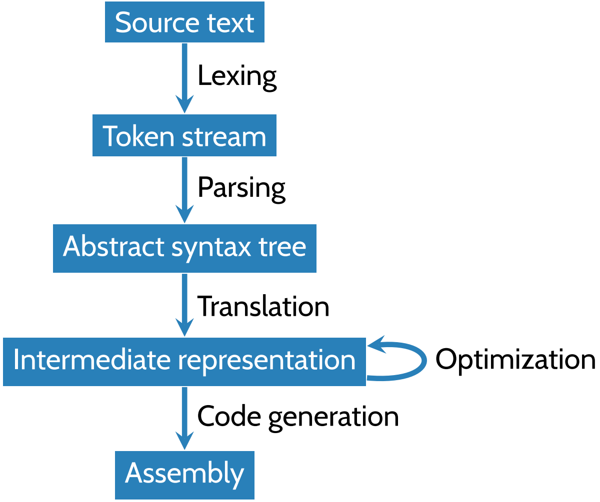
Compiler phases (simplified)



Syntax-directed translation

- Compilation strategy in which *syntax* of the program drives code generation
  - Assembly code generated from abstract syntax tree, or even directly by the parser
  - No substantial code analysis or transformation
- Demo: `sdt.ml`

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    - Assembly code generated from abstract syntax tree, or even directly by the parser
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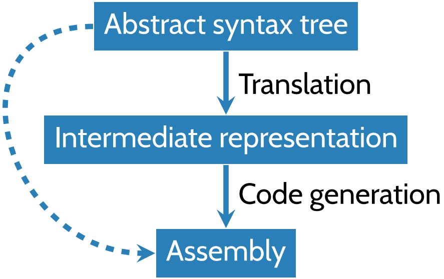
- Easy to implement, but:
    - produces inefficient code
    - can be difficult to implement some language features (e.g., first-class functions)
    - difficult to re-target compiler to new architectures

Intermediate Representations

- An intermediate representation (IR) breaks code generation up into two phases
  1. Translation from source language into IR
  2. Generating target code from IR



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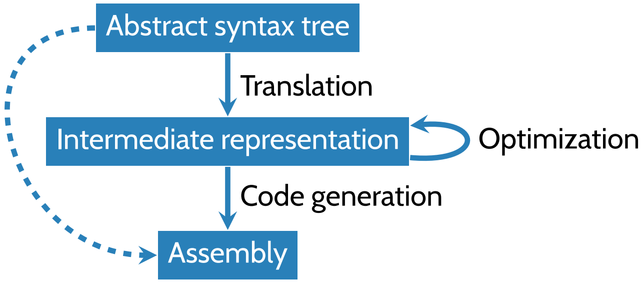
- Good level of abstraction at which to perform optimization



A simple let-based IR (`let.ml`)

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

$$\longrightarrow$$

$$\begin{aligned}
&let\ tmp1 = x + y\\
&let\ tmp2 = 2 * tmp1\\
&let\ tmp3 = z * z\\
&let\ tmp4 = tmp2 - tmp3\\
&x = tmp4
\end{aligned}$$

1. Makes evaluation order explicit (no nested expressions)
2. Names all intermediate values ($\sim$ unboundedly many "virtual" registers)
3. Distinguish between variables & intermediate values

Why use an IR?

- Appropriate abstraction level for machine-independent optimization
  - Simpler, lower-level than source language
  - Retain (some) information from source language that's helpful for analysis & optimization
    - E.g., types, distinguish between writes to memory & computation of intermediate values

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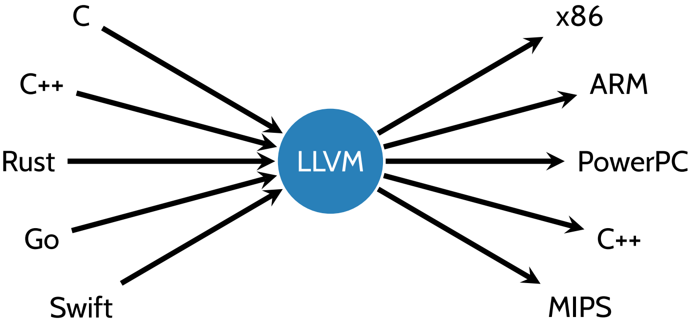
- Safety: IR can enforce maintenance of invariants (e.g. types)
- Reusability
  - IR can mediate between many source & target languages
  - Saves the work of reimplementing optimization & code generation passes

Reusability



What makes a good IR?

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2. Convenient to generate assembly from IR
3. Convenient to manipulate IR during optimization
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1. Convenient to translate source language to IR
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3. Convenient to manipulate IR during optimization
   - Narrow interface $\Rightarrow$ fewer cases to consider
   - E.g., static single assignment (SSA) form enforces that is exactly one assignment to any temporary (as in the `let` IR)
     - Safe to reorder instructions as long as no read/write dependency
     - Dead code analysis is more powerful

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