COS320: Compiling Techniques

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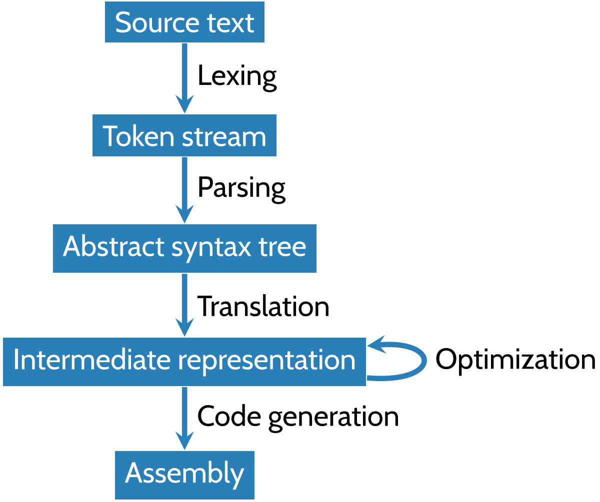
Compiler phases (simplified)



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
  - No substantial code analysis or transformation
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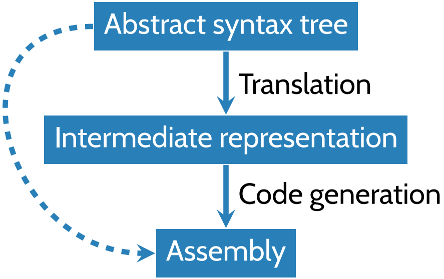
- Easy to implement, but:
  - produces inefficient code
  - can be difficult to implement some language features (e.g., first-class functions)
  - difficult to re-target compiler to new architectures

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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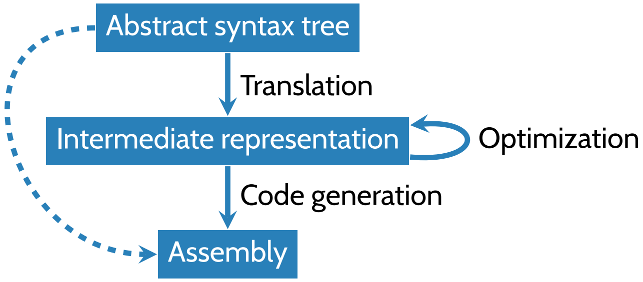
- Good level of abstraction at which to perform optimization



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

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

→

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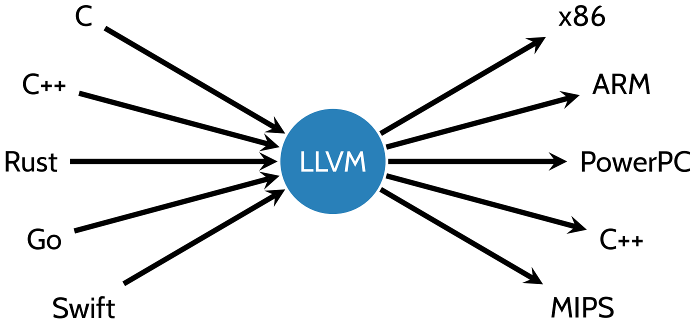
- Safety: IR can enforce maintenance of invariants (e.g. types)
- Reusability
  - IR can mediate between many source & target languages
  - Saves the work of reimplementing optimization & code generation passes

Reusability



What makes a good IR?

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3. Convenient to manipulate IR during optimization
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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