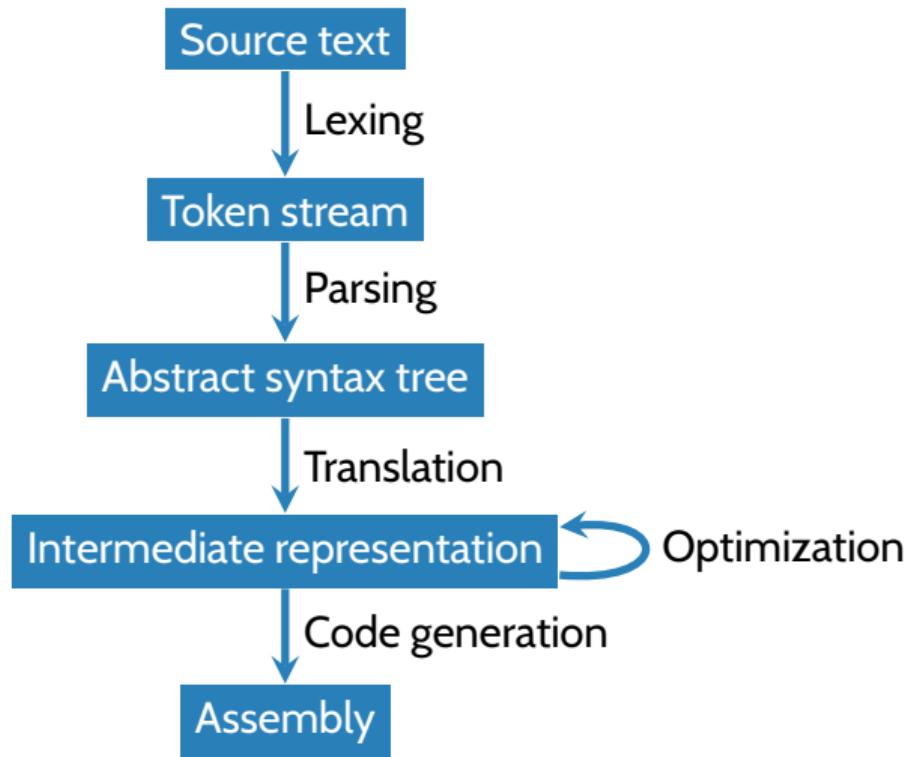


COS320: Compiling Techniques

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Compiler phases (simplified)



Syntax-directed translation

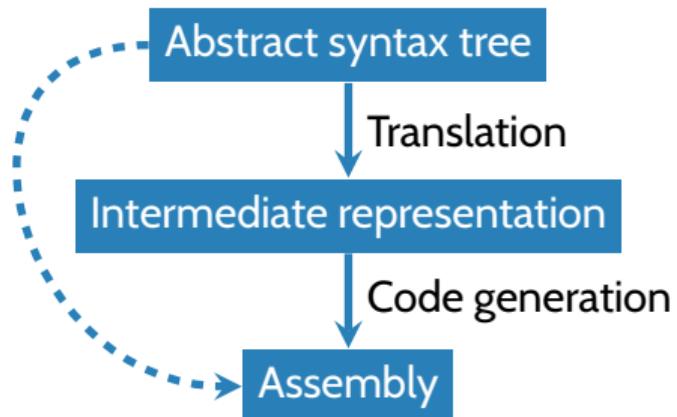
- Compilation strategy in which *syntax* of the program drives code generation
 - Assembly code generated from abstract syntax tree, or even directly by the parser
 - No substantial code analysis or transformation
- Demo: `sdt.ml`

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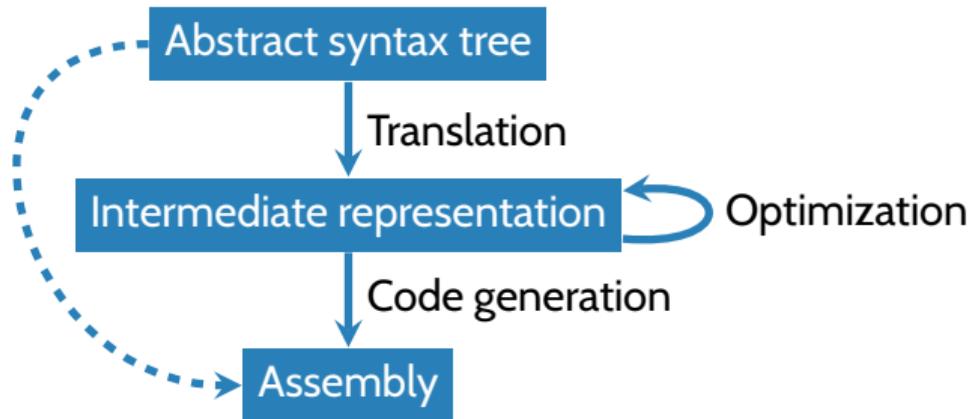
- Compilation strategy in which *syntax* of the program drives code generation
 - Assembly code generated from abstract syntax tree, or even directly by the parser
 - No substantial code analysis or transformation
- Demo: `sdt.ml`
- Easy to implement, but:
 - produces inefficient code
 - can be difficult 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

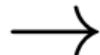


- An intermediate representation (IR) breaks code generation up into two phases
 - ① Translation from source language into IR
 - ② Generating target code from IR
- Good level of abstraction at which to perform optimization



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 (\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

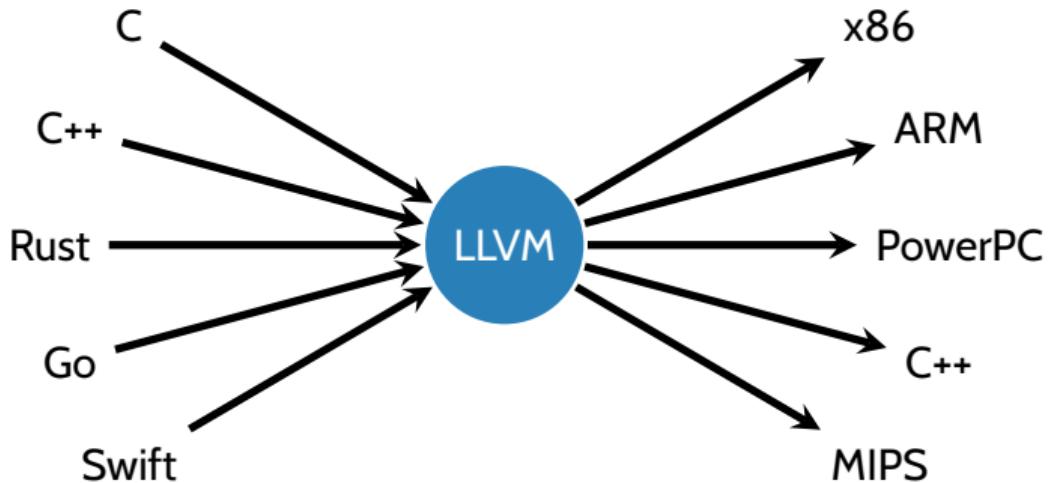
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- Safety: IR can enforce maintenance of invariants (e.g. types)
- Reusability
 - IR can mediate between many source & target languages
 - Saves the work of reimplementing optimization & code generation passes

Reusability



What makes a good IR?

- ① Convenient to translate source language to IR
- ② Convenient to generate assembly from IR
- 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 → GENERIC → GIMPLE → RTL → 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