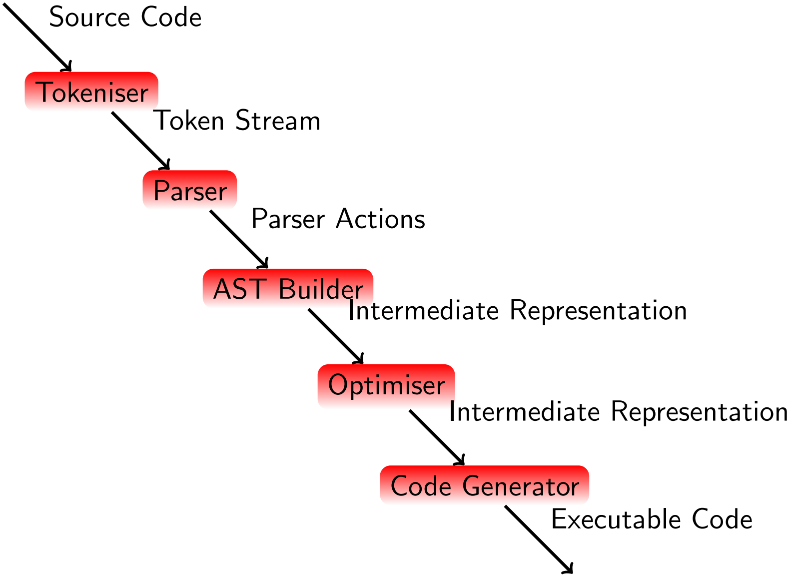
Modern Intermediate Representations (IR)

L25: Modern Compiler Design

Reusable IR

- Modern compilers are made from loosely coupled components
- Front ends produce IR
- Middle ‘ends’ transform IR (optimisation / analysis / instrumentation)
- Back ends generate native code (object code or assembly)

Structure of a Modern Compiler



Source Code

Tokeniser

Token Stream

Parser

Parser Actions

AST Builder

Intermediate Representation

Optimiser

Intermediate Representation

Code Generator

Executable Code

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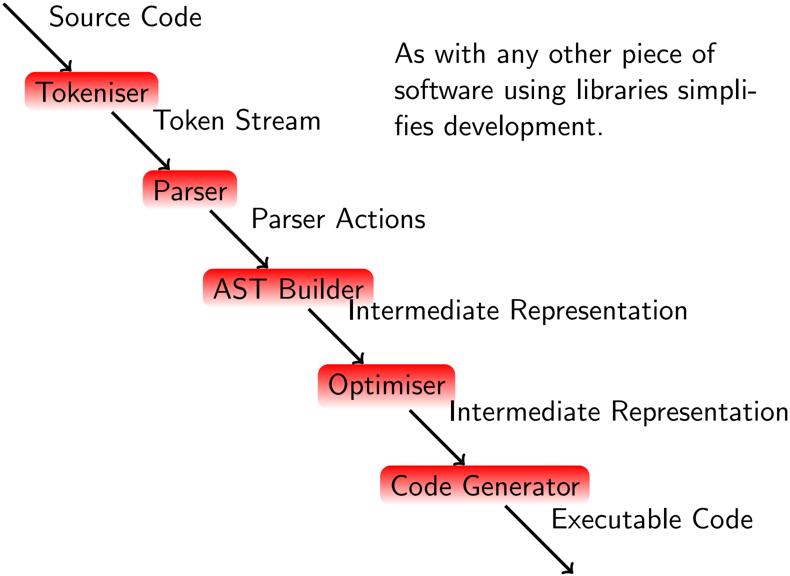

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Executable Code

As with any other piece of software using libraries simplifies development.

Optimisation Passes

- Modular, transform IR (Analysis passes just inspect IR)
- Can be run multiple times, in different orders
- May not always produce improvements in the wrong order!
- Some intentionally pessimise code to make later passes work better

Register vs Stack IR

- Stack makes interpreting, naive compilation easier
- Register makes various optimisations easier
- Which ones?

Common Subexpression Elimination: Register IR

Source language:

```
a = (b+c) * (b+c);
```

```
r1 = load b
r2 = load c
r3 = r1 + r2
r4 = load b
r5 = load c
r6 = r4 + r5
r7 = r3 * r6
store a r6
```

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Common Subexpression Elimination: Stack IR

Source language:

```
a = (b+c) * (b+c);
```

```
load b
load c
add
load b
load c
add
mul
store a
```

Common Subexpression Elimination: Stack IR

Source language:

```
a = (b+c) * (b+c);
```

```
load b
load c
add
dup
mul
store a
```

Problems with CSE and Stack IR

- Entire operation must happen at once (no incremental algorithm)
- Finding identical subtrees is possible, reusing results is harder
- If the operations were not adjacent, must spill to temporary

Hierarchical vs Flat IR

- Source code is hierarchical (contains structured flow control, scoped values)
- Assembly is flat (all flow control is by jumps)
- Intermediate representations are supposed to be somewhere between the two
- Think about how a `for` loop, `while` loop, and `if` statement with a backwards `goto` might be represented.

Hierarchical IR

- Easy to express high-level constructs
- Preserves program semantics
- Preserves high-level semantics (variable lifetime, exceptions) clearly
- Example: WHRIL in MIPSPro/Open64/Path64 and derivatives

Flat IR

- Easy to map to the back end
- Simple for optimisations to process
- Must carry scope information in ad-hoc ways (e.g. LLVM IR has intrinsics to explicitly manage lifetimes for stack allocations)
- Examples: LLVM IR, CGIR, PTX

Questions?