IN2009

**Language Processors**

Session 7

# Translation to Intermediate Representation

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## Session Plan

Session 7: Translation to intermediate representation

- Intermediate representation
- Assembly language - a recap
- Why use IR
- Definition of an IR using trees
- Example translations
- See book for while-loops, for-loops, functions, declarations

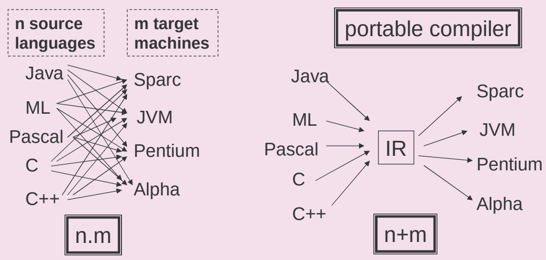


## Intermediate representation

- Semantic analysis
  - converts abstract syntax to abstract machine code (an intermediate rep)
- why an intermediate representation…?



## Intermediate representation



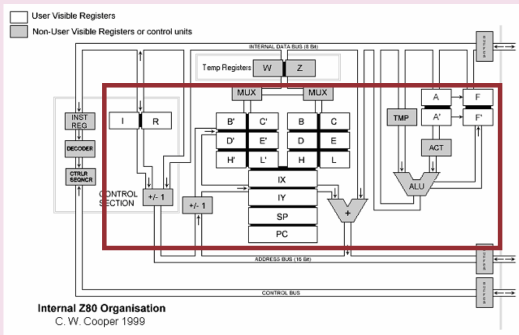



## Assembly Language - a recap

- We've *briefly* considered Processor architecture and memory.
- We've *briefly* considered two architectures
  - Z80A
  - MIPS
- Details of the register sets of each...



## Zilog Z80 (8-bit)



## MIPS R3000 (32-bit)

**Registers**

| Name | Number | Use | Callee must preserve? |
|---|---|---|---|
| $zero | $0 | constant 0 | N/A |
| $at | $1 | assembler temporary | no |
| $v0–$v1 | $2–$3 | Values for function returns and expression evaluation | no |
| $a0–$a3 | $4–$7 | function arguments | no |
| $t0–$t7 | $8–$15 | temporaries | no |
| $s0–$s7 | $16–$23 | saved temporaries | **yes** |
| $t8–$t9 | $24–$25 | temporaries | no |
| $k0–$k1 | $26–$27 | reserved for OS kernel | no |
| $gp | $28 | global pointer | **yes** |
| $sp | $29 | stack pointer | **yes** |
| $fp | $30 | frame pointer | **yes** |
| $ra | $31 | return address | N/A |

*Microprocessor without Interlocked Pipeline Stages*



## Intermediate representation

- We represent the immediate output of the compilation using an *intermediate language* - an abstract machine language
  - Express target machine operations, but without machine-specific details
  - Source-language independent



## Intermediate representation

- Compiler
  - front end: lexical analysis, parsing, semantic analysis
  - back end:
    - optimisation of IR (rewrite IR so as to improve execution speed)
    - translation to real machine language
    - (in case of Java, to another abstract machine language JVM)
- Many IRs
  - Appel uses *simple expression trees*



## Real life IR and ILs

- A wide variety - for example gcc supports (amongst others):
  - RTL (register transfer language), GENERIC (tree-based), GIMPLE (a *static single assignment* language).
- Eiffel uses a simplified form of C.
- Java produces byte code.
- Microsoft .NET uses CIL.
- Other languages operate on pseudo-assembler or generic trees.



## Intermediate representation

- Any good representation:
  - must be convenient for semantic analysis phase to produce.
  - must be convenient to translate to real (or virtual) machine language for target machines.
  - must have simple meaning for each construct that leads to simple operations on the IR to rewrite parts of it for optimisation etc.



## Intermediate representation

- In any IR
  - individual components describe simple operations on the abstract machine represented by the IR instructions
  - each element of the complex abstract syntax is translated into a set of simple IR abstract machine instructions
  - groups of IR instructions will be grouped and regrouped to form real machine instructions

## IR: tree expression operators

- `CONST(i)`
  - integer constant
- `NAME(n)`
  - symbolic constant (an assembly lang label)
- `TEMP(t)`
  - abstract register...infinite number!
- `BINOP(o,e1,e2)`
  - Where o = PLUS, MINUS, MUL, DIV, AND, OR, XOR, LSHIFT, RSHIFT, ARSHIFT



## IR: tree expression operators

- `MEM(e)`
  - contents of wordSize bytes starting at addr e (means "store" if left child of move, else "fetch")
- `CALL(f,l)`
  - procedure call, applies f to list l
- `ESEQ(s,e)`
  - eval s for side-effects, eval e for result



## IR: statements

perform side effects & control flow

- `MOVE(TEMP t,e)`
  - eval e & move into temp t
- `MOVE(MEM(e1,k),e2)`
  - eval e1 ( ⇒ addr a); eval e2 & store results into k bytes of mem starting at a
- `EXP(e)`
  - eval e & discard the result

No provision for procedure and & function defs - just body of each function



## IR: statements

- `JUMP(e,labs)`
  - transfer control to addr e; labs specifies list of all poss locations e can eval to
- `CJUMP(o,e1,e2,t,f)`
  - eval e1 then e2, compare result with relational op o; if true jump to t else to f
- `SEQ(s1,s2)`
  - ???
- `LABEL(n)`
  - defines const n to be current machine code address

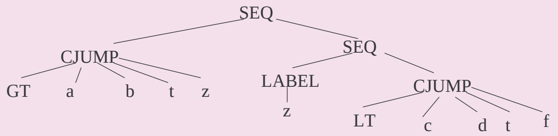


## Example translation

a > b | c < d *translates to*

```
SEQ(CJUMP(GT,a,b,t,z),
    SEQ(LABEL z,
        CJUMP(LT,c,d,t,f)))
```

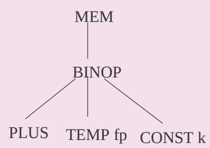
*with* t,f *labels*






## Simple variables translation

- Simple variable v in current procedure or function stack frame
  - k: offset of v in frame
  - `TEMP fp`: frame pointer register




MEM(BINOP(PLUS,TEMP fp, CONST k))

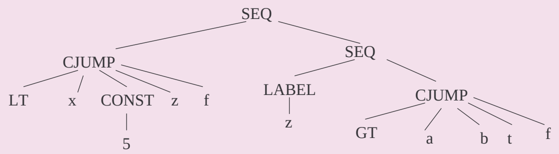
## Conditionals

- Use `CJUMP`
  - x < 5 translates to **`CJUMP(LT, x, CONST(5), t, f)`**
  - for labels `t`, `f`
- if x < 5 then a > b else 0



## Conditionals

```
SEQ(CJUMP(LT,x,CONST(5),z,f),
  SEQ(LABEL z,
     CJUMP(GT,a,b,t [pick up val of a>b],f  [pick up val 0])))
```






## What you should do now

- See book for other translations
  - while-loops
  - for-loops
  - functions
  - declarations
- Complete the May 2006 exam paper before next week!



## Schedule

- ***Module Summary & Exam Revision***
- Monday 2nd April, 2007
  - 12:00 - 13:50
  - CM383