Compiler Construction

Lecture 23: Code Generation VIII (Generation of Machine Code)

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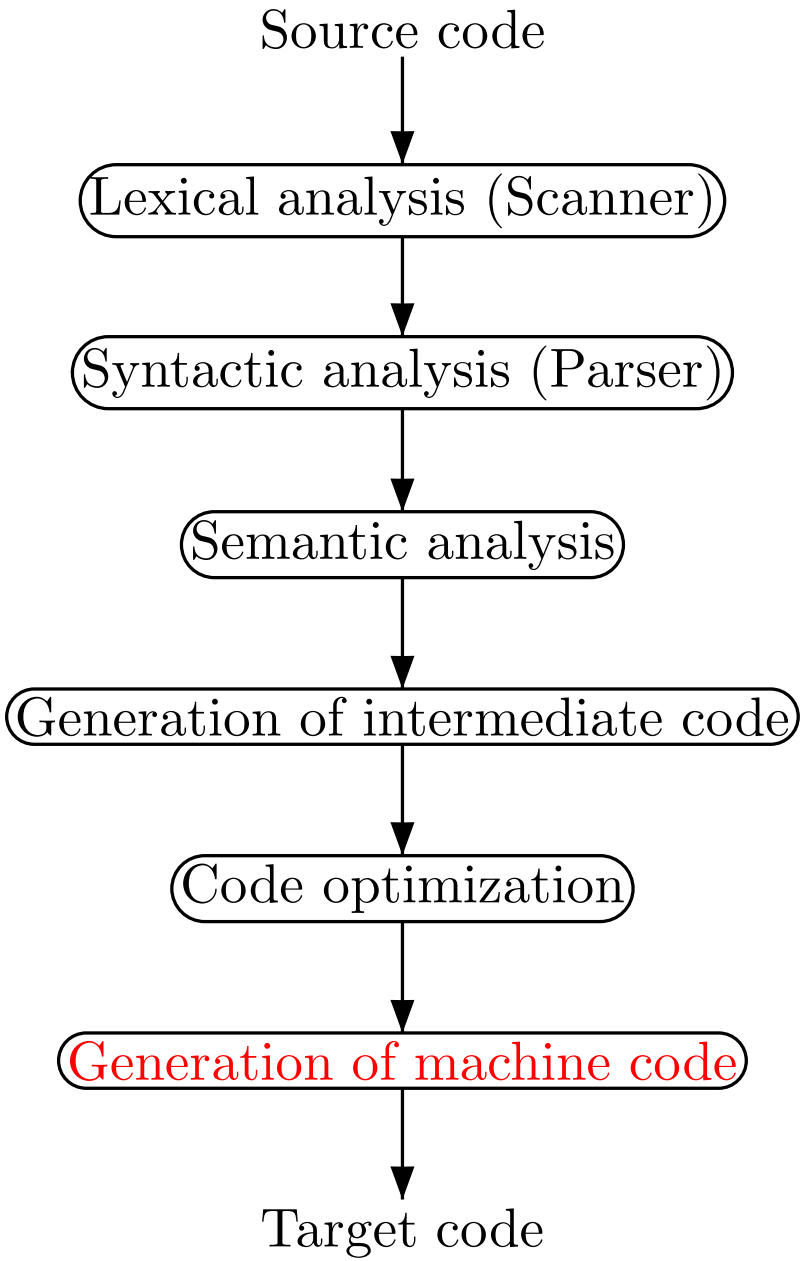
Summer semester 2008

Outline

1 Generation of Machine Code

2 Wrap-Up

Conceptual Structure of a Compiler



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- cache ("fast" RAM)
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Instruction set: depending on

- number of operands
- type of operands
- addressing modes

Code Generation Phases

1. Register allocation: registers used for
   - values of (frequently used) variables and intermediate results
   - computing memory addresses
   - passing parameters to procedures/functions
2. Instruction selection:
   - translation of abstract instructions into (sequences of) real instructions
   - employ special instructions for efficiency (e.g., `INC(x)` rather than `ADD(x,1)`)
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- **Idea:** start with register-intensive subexpressions

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    4. combine results
  - if $r_2 < r_1 \leq r$, then e can be evaluated using r_1 registers
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- The corresponding optimization algorithm works in two phases:
  1. Marking phase (computes r_i values)
  2. Generation phase (produces actual code)

  (for details see Wilhelm/Maurer: *Übersetzerbau, 2. Auflage*, Springer, 1997, Sct. 11.4)

The Marking Phase

Algorithm 23.2 (Marking phase)

Input: *expression (with binary operators op and variables x)*

Procedure: *recursively compute*

$$r(x) := \begin{cases} 1 & \text{if } x \text{ is a “left leaf”} \\ 0 & \text{if } x \text{ is a “right leaf”} \\ 1 & \text{if } x \text{ is at the root} \end{cases}$$

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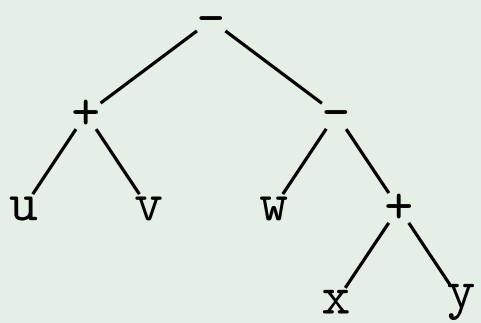

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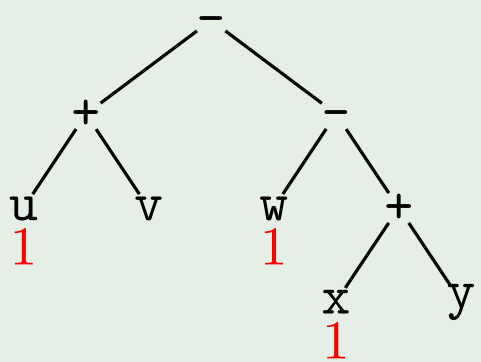

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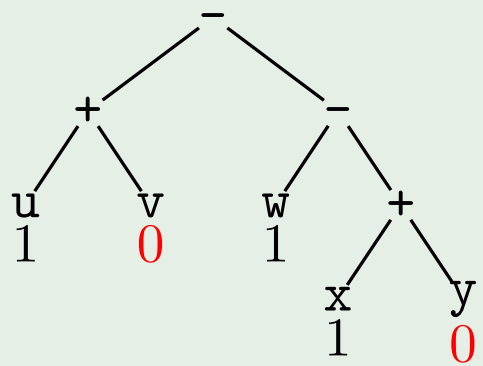

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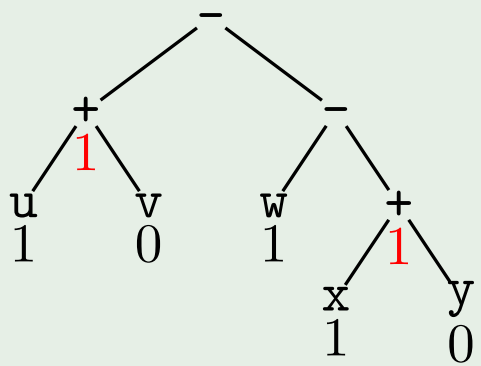

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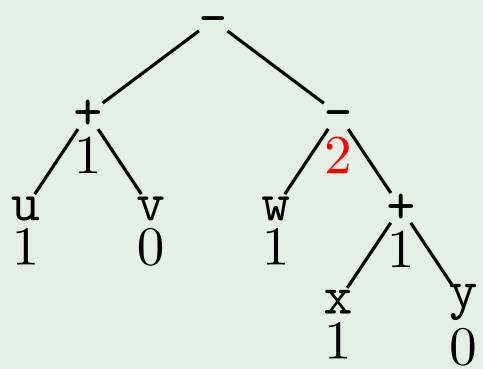

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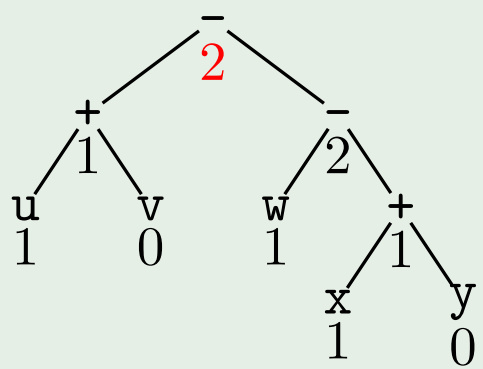

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- Data structures used in Algorithm 23.4:

  RS: stack of available registers (initially: all registers; never empty)

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- Auxiliary procedures used in Algorithm 23.4:

  output: outputs the argument as code

  top: returns the topmost entry of a stack S (leaving S unchanged)

  pop: removes and returns the topmost entry of a stack

  push: puts an element onto a stack

  exchange: exchanges the two topmost elements of a stack

The Generation Phase II

Algorithm 23.4 (Generation phase)

Input: *expression e, annotated with register requirement $r(e)$*

Variables: *RS: stack of registers;*
CS: stack of memory cells;
R: register; C: memory cell;

Procedure: *recursive execution of procedure $code(e)$, defined by $code(e) :=$*

if $e = x$, $r(x) = 1$: % left leaf
  $output(top(RS)$:= M[x]$)$

if $e = e_1$ op y, $r(y) = 0$: % right leaf
  $code(e_1)$;
  $output(top(RS)$:=$top(RS)$ op M[y]$)$

if $e = e_1$ op e_2, $r(e_1) < r(e_2)$, $r(e_1) < r$:
  $exchange(RS)$;
  $code(e_2)$;
  $R := pop(RS)$;
  $code(e_1)$;
  $output(top(RS)$:=$top(RS)$ op $R)$;
  $push(RS, R)$;
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if $e = e_1$ op e_2, $r(e_1) \geq r(e_2)$, $r(e_2) < r$:
  $code(e_1)$;
  $R := pop(RS)$;
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  $output(R$:=R op $top(RS))$;
  $push(RS, R)$

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  $code(e_2)$;
  $C := pop(CS)$;
  $output($M[C]:=$top(RS))$;
  $code(e_1)$;
  $output(top(RS)$:=$top(RS)$ op M[C]$)$;
  $push(CS, C)$

Output: *optimal (= shortest) code for evaluating e*

The Generation Phase III

- Invariants of Algorithm 23.4:
  - after executing $code(e)$, both RS and CS have their original values
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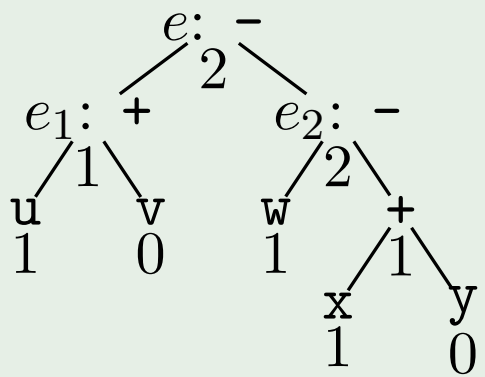

(on the board)

Outline

1 Generation of Machine Code

2 Wrap-Up

Omitted

- Code optimization
- Translation of higher-level constructs (modules, classes)
- Translation of non-procedural languages
  - object-oriented (polymorphism, dynamic dispatch)
  - functional (higher-order functions, typechecking)
  - logic (unification, backtracking)
- Bootstrapping

Outlook

Winter semester 2008/09:

- *Introduction to Model Checking* [Katoen; V4Ü2]
- *Semantics and Verification of Software* [Noll; V4Ü2]
- [Seminar *Timed Automata*]

Course Evaluation

Discussion:

- – More examples
- – Lecture sometimes too fast
- – Slides sometimes to full
- – Some handouts inappropriate for printing
- – Curtain in AH 2
- \+ Repetition in beginning of lecture