Compiler Construction

Lecture 25: Generation of Machine Code

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(Software Modeling and Verification)

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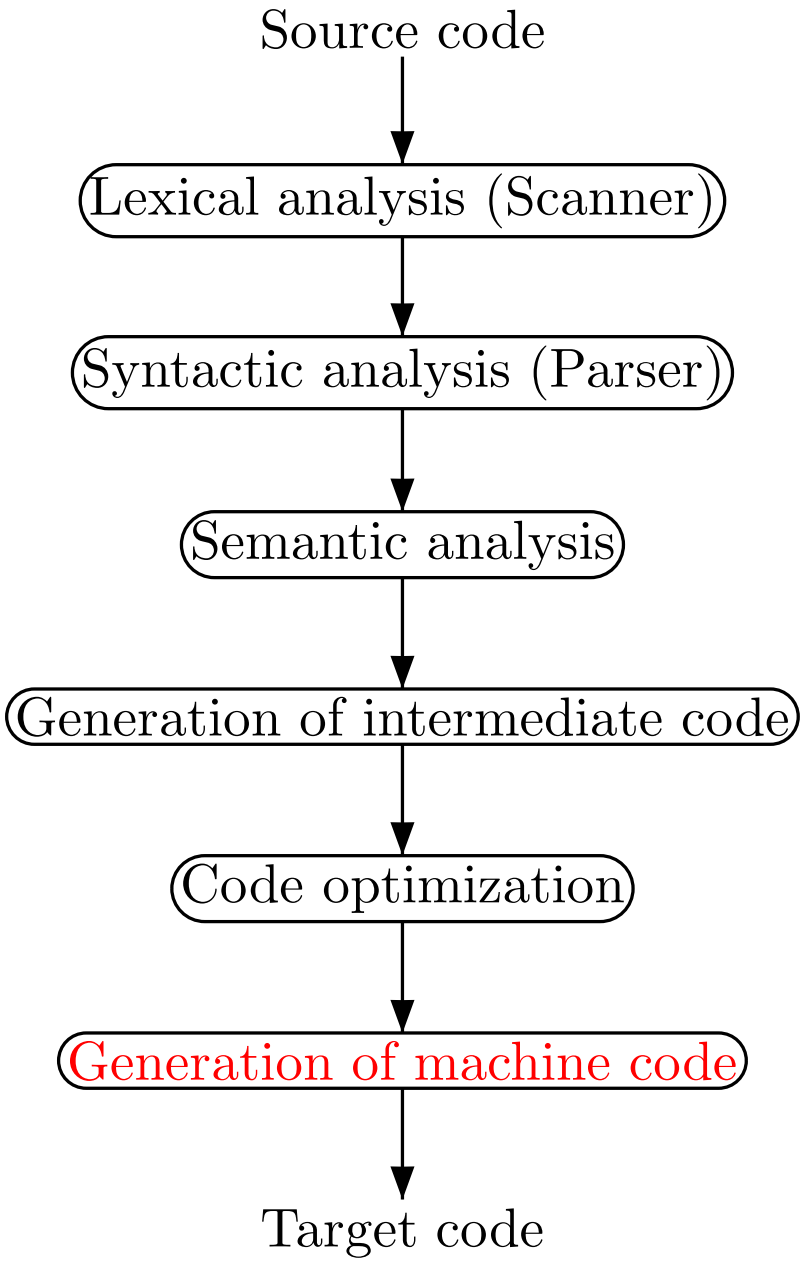
Online Evaluation of CS Curricula

`http://www.campus.rwth-aachen.de/evasys/index.php?mca=online/index/`

- In German
- Losung: `autobahn`
- Advisory service, preparatory CS course
- Conditions of study
- Applied subject
- ...

Outline

Conceptual Structure of a Compiler



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- registers (program counter, data [universal/floating point/address], frame pointer, index register, condition code, ...)
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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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  - 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 25.2 (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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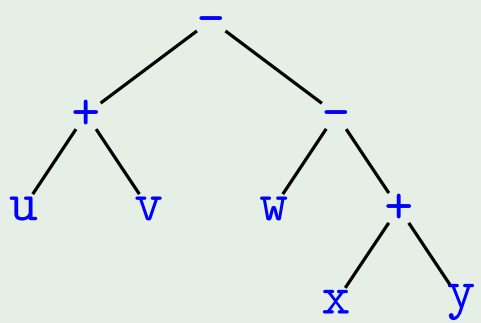

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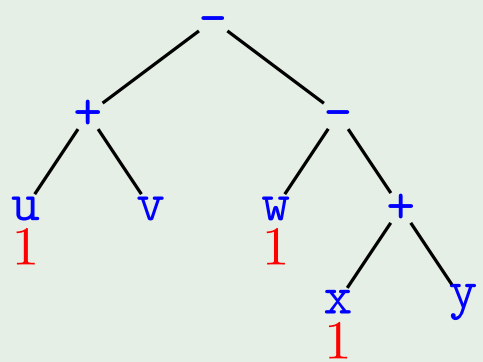

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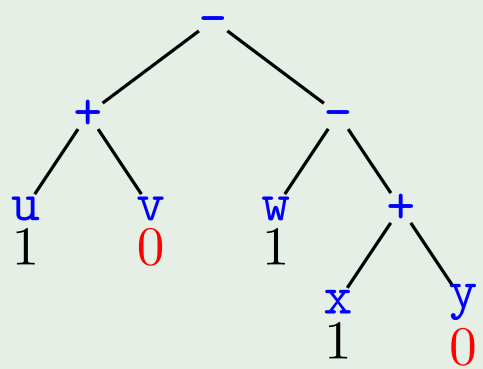

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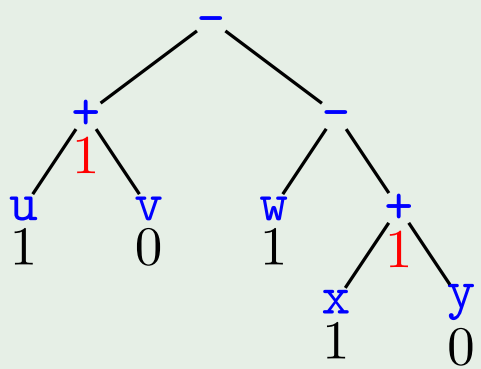

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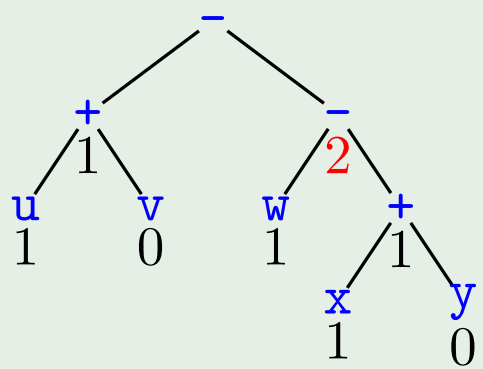

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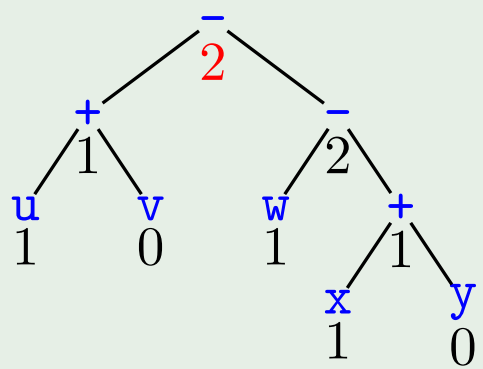

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- Data structures used in Algorithm 25.4:

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- Auxiliary procedures used in Algorithm 25.4:

  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 25.4 (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 $code(e) :=$*

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

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

(3) 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);
exchange(RS)

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

(5) if $e = e_1$ op e_2, $r(e_1) \geq r$, $r(e_2) \geq r$:
$code(e_2)$;
$C := pop(CS)$;
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 25.4:
  - after executing $code(e)$, both RS and CS have their original values
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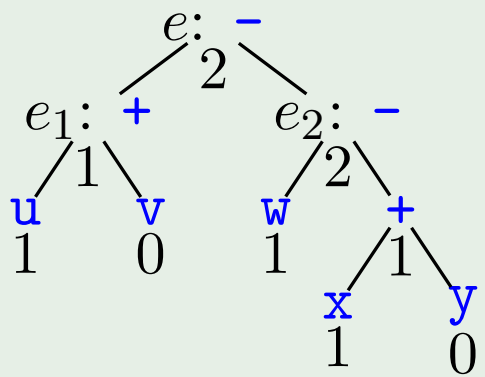

(on the board)