Compiler Construction

Lecture 1: Introduction

Thomas Noll

Lehrstuhl für Informatik 2
(Software Modeling and Verification)

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http://www-i2.informatik.rwth-aachen.de/i2/cc08/

Summer semester 2008

Outline

1. Preliminaries

2. Introduction

People

- Lectures: Thomas Noll
  - Lehrstuhl für Informatik 2, Room 4211
  - E-mail `noll@cs.rwth-aachen.de`
  - Phone (0241)80-21213
- Exercise classes: Daniel Klink
  - Lehrstuhl für Informatik 2, Room 4205
  - E-mail `klink@cs.rwth-aachen.de`
  - Phone (0241)80-21210
- Student assistants:
  - Johanna Nellen (`johanna.nellen@rwth-aachen.de`)
  - Maximilian Odenbrett (`maximilian.odenbrett@rwth-aachen.de`)

Target Audience

- Bachelor program (Informatik): V3 Ü2
  - Wahlpflichtfach Theorie
- Master programs (Software Systems Engineering [, Informatik]): V4 Ü2
  - Theoretical (+ Practical) CS
  - Specialization *Formal Methods, Programming Languages and Software Validation*
- Diplomstudiengang (Informatik): V4 Ü2
  - Theoretische (+ Praktische) Informatik
  - Vertiefungsfach *Formale Methoden, Programmiersprachen und Softwarevalidierung*
- In general:
  - interest in implementation of (imperative) programming languages
  - application of theoretical concepts
  - compiler = example of a complex software architecture
  - gaining experience with tool support
- Expected: basic knowledge in
  - imperative programming languages
  - formal languages and automata theory

Organization

- Schedule:
  - Lecture Mon 10:00–11:30 AH 2 (starting April 14)
  - Lecture Thu 15:00–16:30 AH 5
  - Exercise class Wed 13:30–15:00 AH 3 (starting 23.10.2006)

  (see overview at `http://www-i2.informatik.rwth-aachen.de/i2/cc08/`)
- Today: 0th assignment sheet, presented next Wednesday
- Work on assignments in groups of three
- Examination:
  - oral for BSc candidates (6 ECTS credit points)
  - otherwise (8 ECTS credit points) depending on number of candidates
- Admission requires at least 50% of the points in the (non-Diplom) exercises
- Written material in English, lecture and presentation of assignments in German, rest up to you

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What Is It All About?

Compiler = Program: Source code → Machine code

Source code: in high-level programming language, tailored to problem
(imperative/declarative [functional, logic]/
object-oriented, sequential/concurrent)

Machine code: architecture dependent
(von Neumann; RISC/CISC/parallel)

What Is It All About?

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Important issues:

Correctness: "equivalence" of source and machine code ($\Longrightarrow$ compiler verification, proof-carrying code, ...)

Efficiency of generated code: machine code as fast and/or memory efficient as possible ($\Longrightarrow$ program analysis and optimization)

Efficiency of compiler: translation process as fast and/or memory efficient as possible ($\Longrightarrow$ sophisticated algorithms and data structures; bootstrapping)

Efficiency depends on system environment (mutual tradeoff)

Aspects of a Programming Language

Syntax: "How does a program look like?"
(hierarchical composition of programs from structural components)

Semantics: "What does this program mean?"

- "Static semantics": properties which are not (easily) definable in syntax
  (declaredness of identifiers, type correctness, ...)
- "Dynamic semantics": execution evokes state transformations of an [abstract] machine

Pragmatics:

- length and understandability of programs
- learnability of programming language
- appropriateness for specific applications
- ...

Historic development

- Formal syntax since 1960s (LL/LR parsing); semantics defined by compiler/interpreter
- Formal semantics since 1970s (operational/denotational/axiomatic)
- Automatic compiler generation since 1980s (`[f]lex`, `yacc`, action semantics, ...)

Motivation for Rigorous Formal Treatment

Examples:

1. How often is the following loop traversed?

```
for i := 2 to 1 do ...
```

FORTRAN IV: once
PASCAL: never

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PASCAL: never

2. What if `p = nil` in the following program?

```
while p <> nil and p^.key < val do ...
```

Pascal: strict Boolean operations ↓
Modula: non-strict Boolean operations ↑

Compiler Phases

Lexical analysis (Scanner):

- recognition of symbols, delimiters, and comments
- by regular expressions and finite automata

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- checking context dependencies, data types, ...
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Generation of intermediate code:

- translation into (target-independent) intermediate code
- by tree translations

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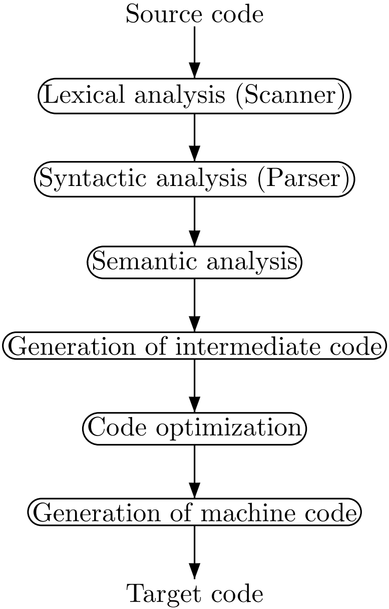
Generation of target code: tailored to target system

Additionally: optimization of target code, symbol table, error handling

Conceptual Structure of a Compiler



Source code

Lexical analysis (Scanner)

Syntactic analysis (Parser)

Semantic analysis

Generation of intermediate code

Code optimization

Generation of machine code

Target code

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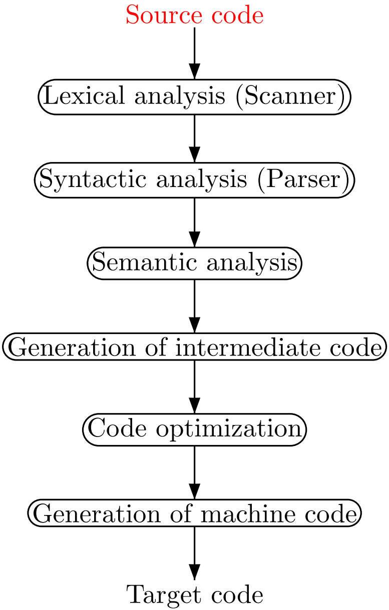

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Target code

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x1 := y2 + 1
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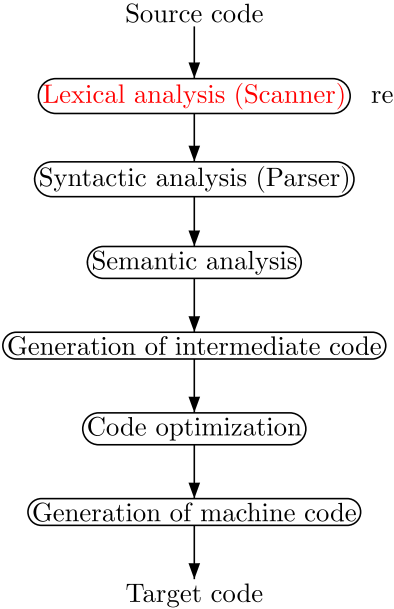

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Code optimization

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regular expressions/finite automata

(id, x1)(gets,)(id, y2)(plus,)(int, 1)

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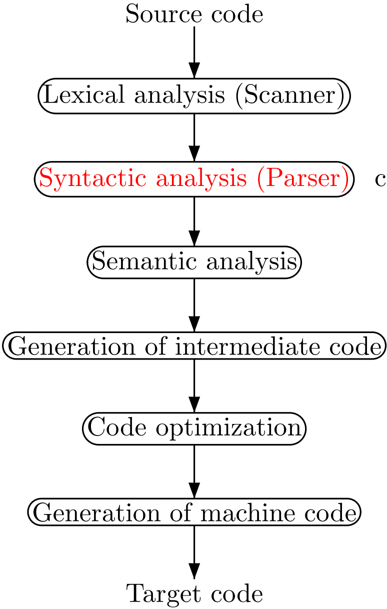

Source code

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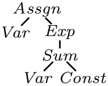
context-free grammars/pushdown automata



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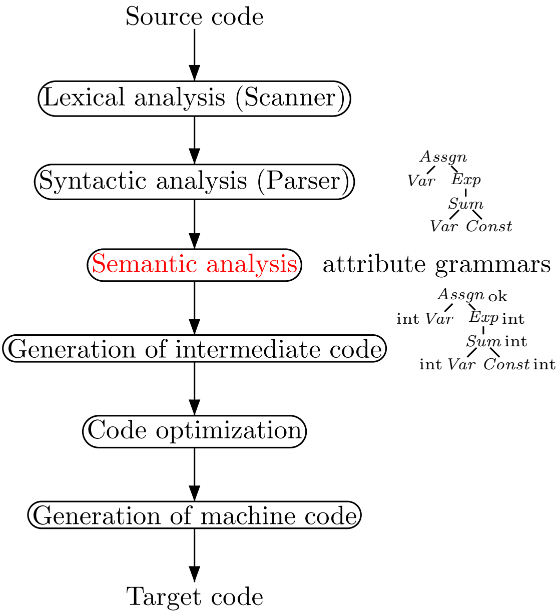

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attribute grammars

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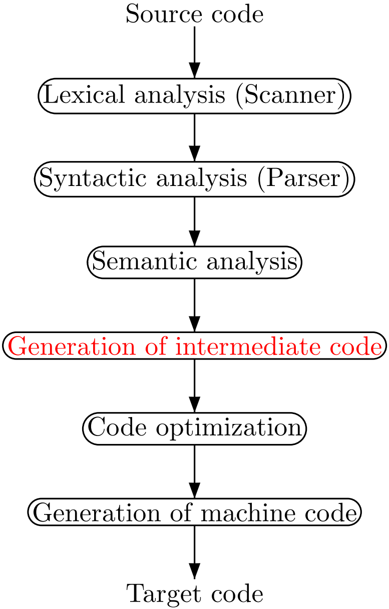
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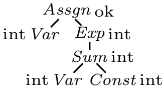

tree translations

```
LOAD y2; LIT 1; ADD; STO x1
```

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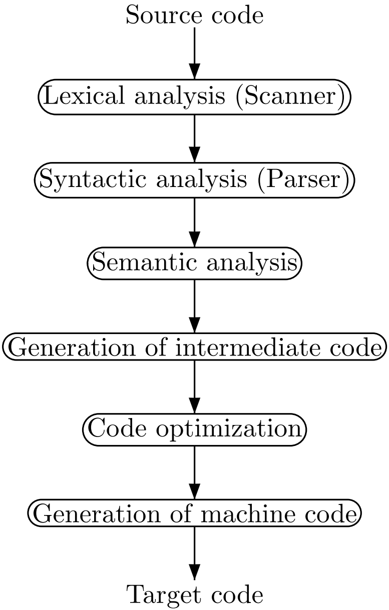
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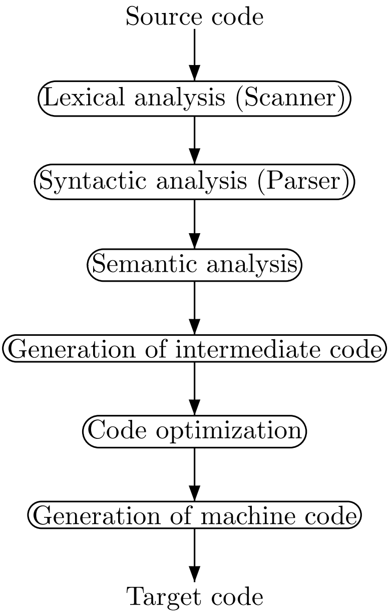

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[omitted: symbol table, error handling]

Classification of Compiler Phases

Analysis:	lexical/syntactic/semantic analysis (determination of syntactic structure, error handling)
Synthesis:	generation of (intermediate/machine) code + optimization

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(analysis + intermediate code + machine-independent optimizations)

Backend: machine-dependent parts
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Another classification: n-pass compiler
(number of runs through source program; nowadays mainly one-pass)

Literature

(also see the collection [“Handapparat”] at the CS Library)

- A. Aho, R. Sethi, J. Ullman: *Compilers – Principles, Techniques, and Tools*, Addison-Wesley, 1988
- W. Waite, G. Goos: *Compiler Construction, 2nd edition*, Springer, 1985
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