Compiler Construction

Lecture 1: Introduction

Thomas Noll

Lehrstuhl für Informatik 2
(Software Modeling and Verification)

RWTH Aachen University

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http://www-i2.informatik.rwth-aachen.de/i2/cc12/

Summer Semester 2012

Outline

People

- Lectures:
  - Thomas Noll (noll@cs.rwth-aachen.de)
  - Uwe Naumann (naumann@stce.rwth-aachen.de)
- Exercise classes:
  - Friedrich Gretz (fgretz@cs.rwth-aachen.de)
  - Christina Jansen (christina.jansen@cs.rwth-aachen.de)

Wanted: Student Assistant

- Evaluation of exercises
- Organizational support
- 12 hrs/week contract
- Previous CC lecture not a prerequisite (but of course helpful)

Target Audience

- BSc Informatik:
  - Wahlpflichtfach Theorie
- MSc Informatik:
  - Theoretische Informatik
- MSc Software Systems Engineering:
  - Theoretical Foundations of SSE (was: Theoretical CS)
- Diplomstudiengang Informatik:
  - Theoretische (+ Praktische) Informatik
  - Vertiefungsfach *Formale Methoden, Programmiersprachen und Softwarevalidierung*
  - Combination with Katoen, Thomas, Vöcking, ...; Kobbelt, Seidl, ...

Expectations

- What you can expect:
  - how to implement (imperative) programming languages
  - application of theoretical concepts
  - compiler = example of a complex software architecture
  - gaining experience with tool support

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  - how to implement (imperative) programming languages
  - application of theoretical concepts
  - compiler = example of a complex software architecture
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- What we expect: basic knowledge in
  - imperative programming languages
  - algorithms and data structures
  - formal languages and automata theory

Organization

- Schedule:
  - Lecture Wed 10:00–11:30 AH 6 (starting 4 April)
  - Lecture Thu 15:00–16:30 AH 5 (starting 5 April)
  - Exercise class Mon 10:00–11:30 AH 2 (starting 16 April)
  - see overview at http://www-i2.informatik.rwth-aachen.de/i2/cc12/

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- Written material in English, lecture and exercise classes in German, rest up to you

Outline

What Is It All About?

Compiler = Program: Source code → Target code

Source code: in high-level programming language, tailored to problem

- imperative vs. declarative (functional, logic) vs. object-oriented
- sequential vs. concurrent

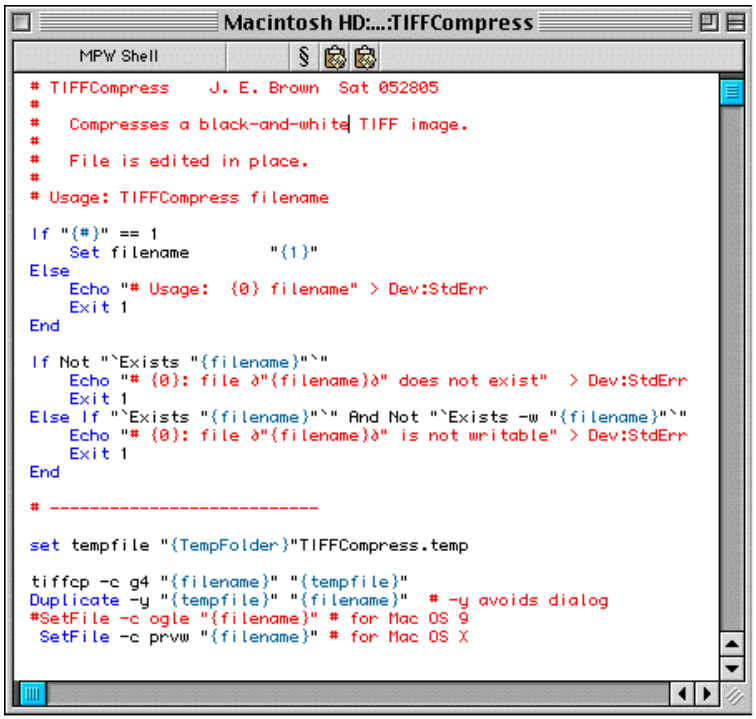
Target code: usually byte/assembly/machine code, tailored to machine

- architecture dependent (RISC/CISC/parallel)

Usage of Compiler Technology I

Programming language interpreters

- Ad-hoc implementation of small programs in scripting languages (perl, bash, ...)
- Programs usually interpreted, i.e., executed stepwise
- Moreover: many non-scripting languages involve interpreters (e.g., JVM as byte code interpreter)



Usage of Compiler Technology II

Web browsers

- Receive HTML (XML) pages from web server
- Analyse (parse) data and translate it to graphical representation

```
1  <!DOCTYPE html PUBLIC "-//W3C//DTD HTML
2  <html>
3      <head>
4          <title>Example</title>
5          <link href="screen.css" rel="sty
6      </head>
7      <body>
8          <h1>
9              <a href="/">Header</a>
10         </h1>
11         <ul id="nav">
12             <li>
13                 <a href="one/">One</a>
14             </li>
15             <li>
16                 <a href="two/">Two</a>
17             </li>
```

Usage of Compiler Technology III

Text processors

- LaTeX = "programming language" for texts of various kinds
- Translated to DVI, PDF, ...

```
\documentclass[12pt]{article}
%options include 12pt or 11pt or 10pt
%classes include article, report, book, letter, thesis
\title{This is the title}
\author{Author One \\ Author Two}
\date{\today}
\begin{document}
\maketitle
This is the content of this document.
This is the 2nd paragraph.
Here is an inline formula:
$V=\frac{4 \pi r^3}{3}$
And appearing immediately below
is a displayed formula:
$$V=\frac{4 \pi r^3}{3}$$
\end{document}
```

Properties of a Good Compiler

Correctness

Goals: conformance to source and target language specifications;
"equivalence" of source and target code

- compiler validation and verification
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Remark: mutual tradeoffs!

Aspects of a Programming Language

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Pragmatics

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

Motivation for Rigorous Formal Treatment

Example

1. From NASA's Mercury Project: FORTRAN `DO` loop
   - `DO 5 K = 1,3`: DO loop with index variable `K`
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2. How often is the following loop traversed?

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for i := 2 to 1 do ...
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FORTRAN IV: once

PASCAL: never

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   ```

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   PASCAL: never
3. 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 ✓

Historical Development

Code generation: since 1940s

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Automatic compiler generation: since 1980s

- `[f]lex`, `yacc`, ANTLR, action semantics, ...
- see `http://catalog.compilertools.net/`

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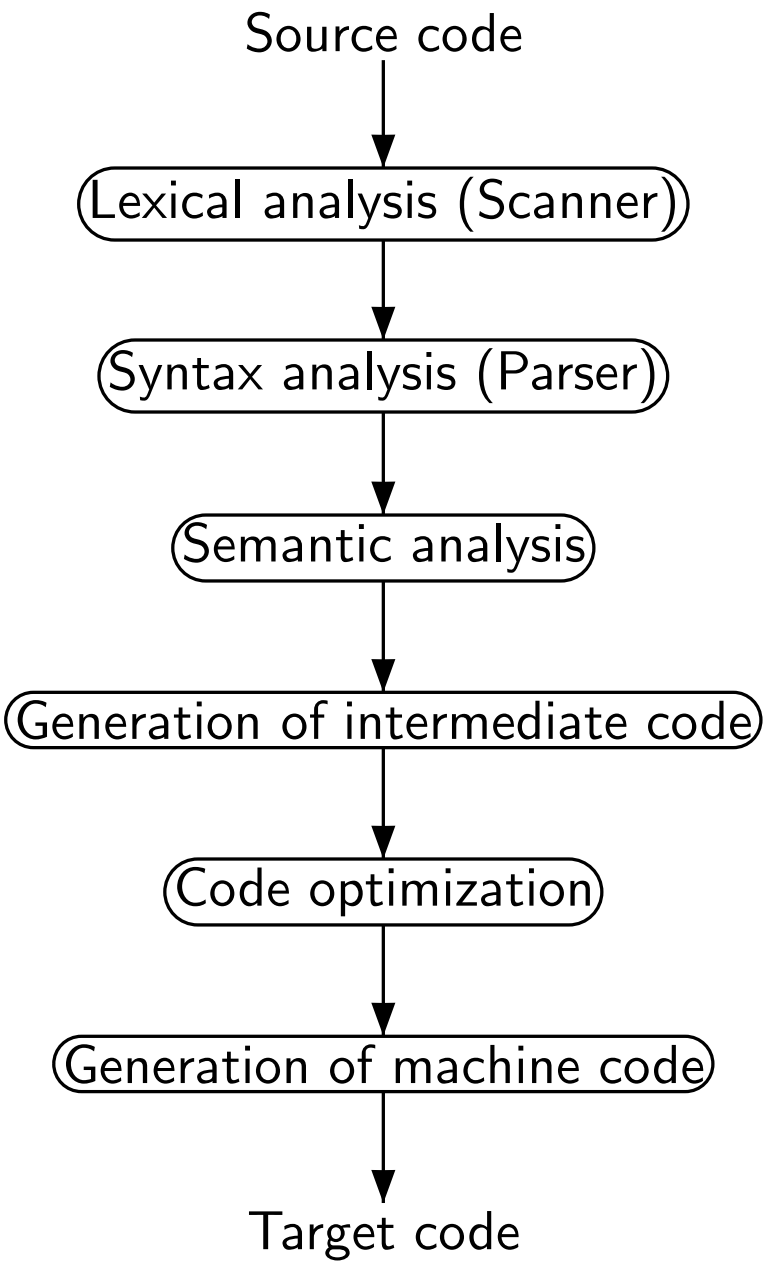
Code optimization: to improve runtime and/or memory behavior

Generation of target code: tailored to target system

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

Conceptual Structure of a Compiler



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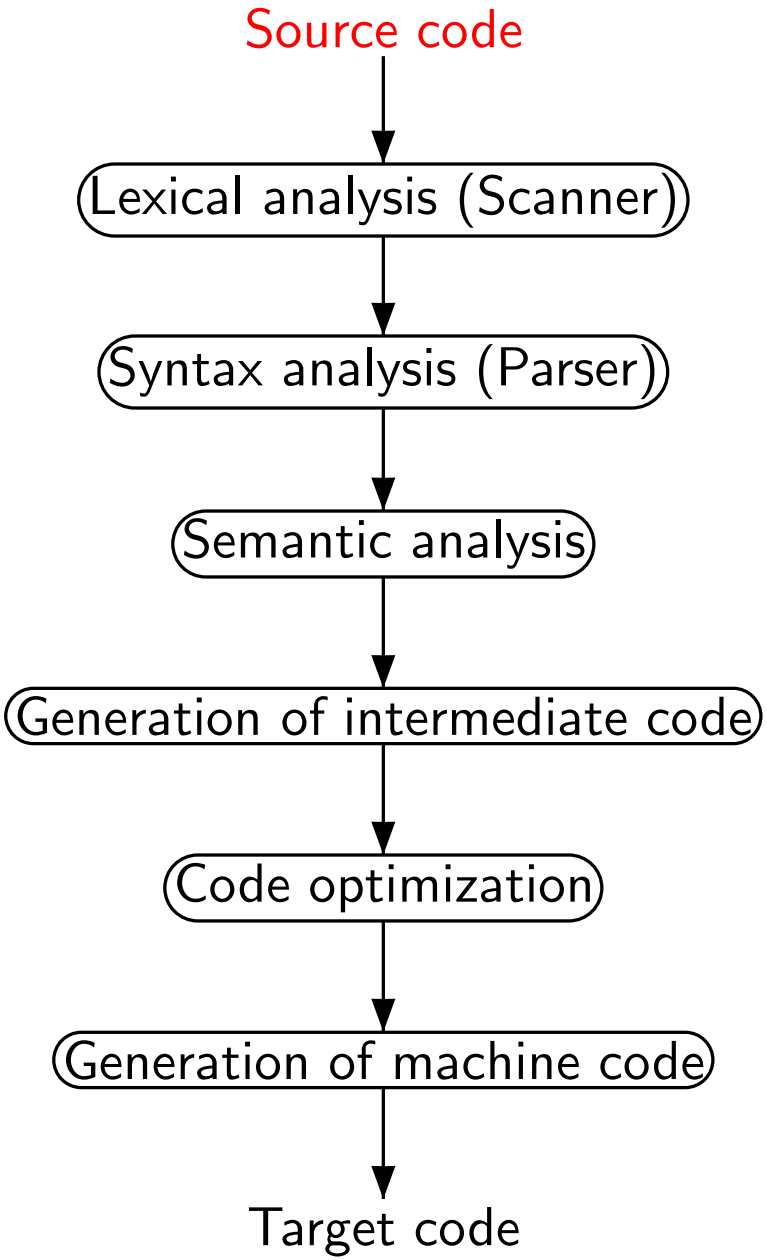


```
x1 := y2 + 1
```

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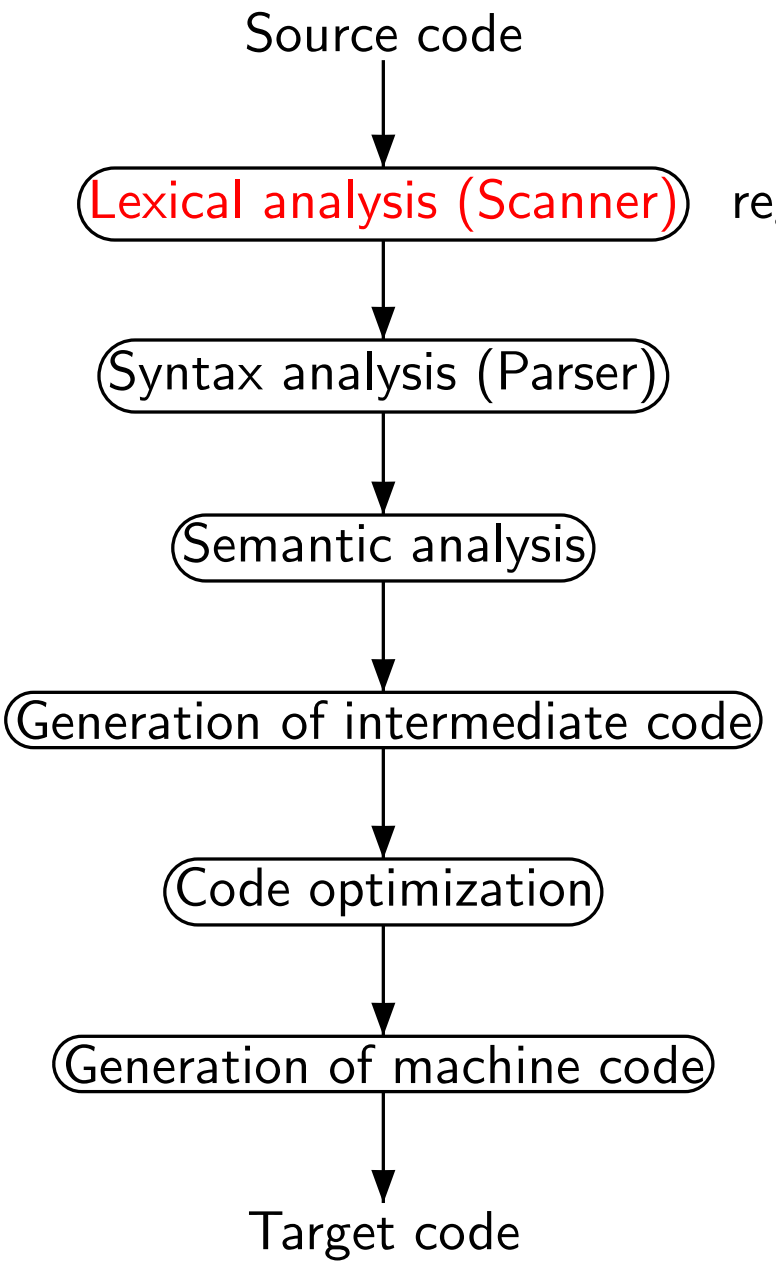

`x1 := y2 + 1`

regular expressions/finite automata

$(\mathrm{id}, \mathtt{x1})(\mathrm{gets},)(\mathrm{id}, \mathtt{y2})(\mathrm{plus},)(\mathrm{int}, 1)$

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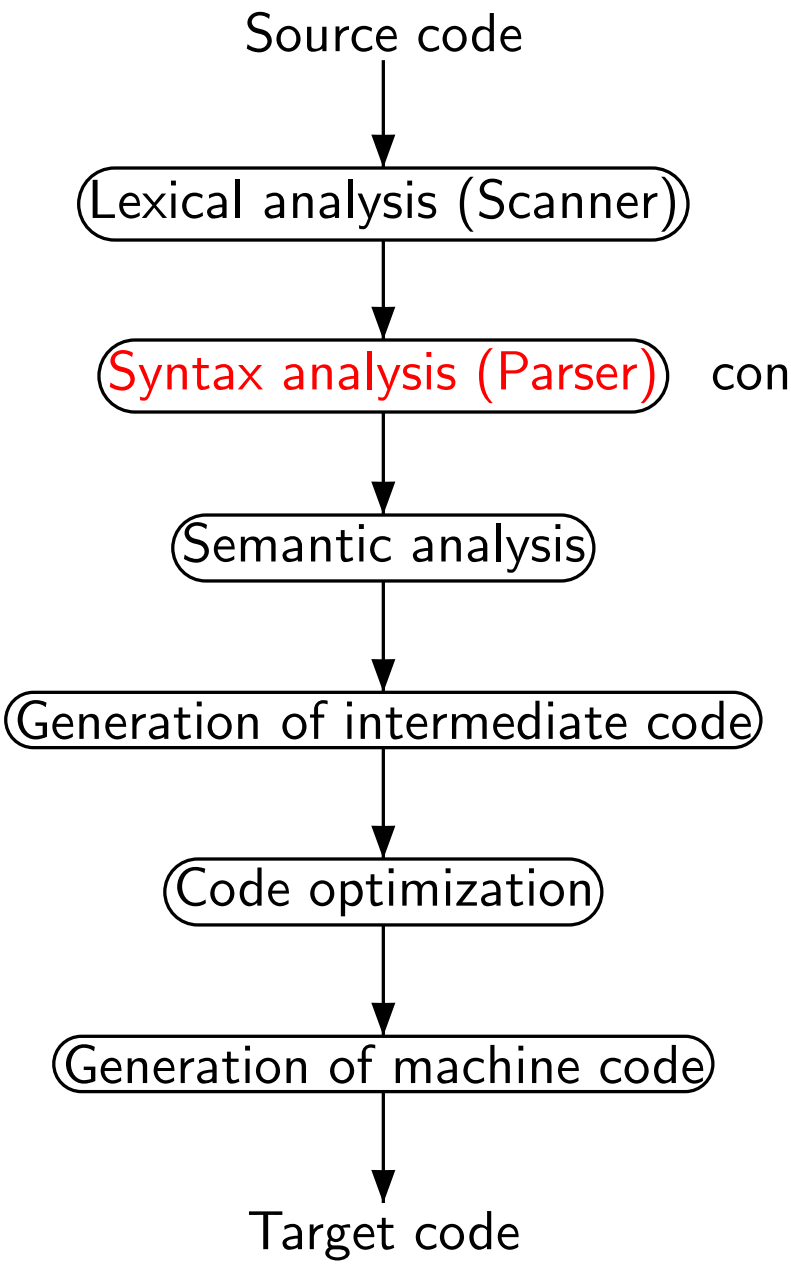

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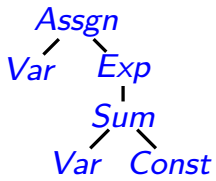

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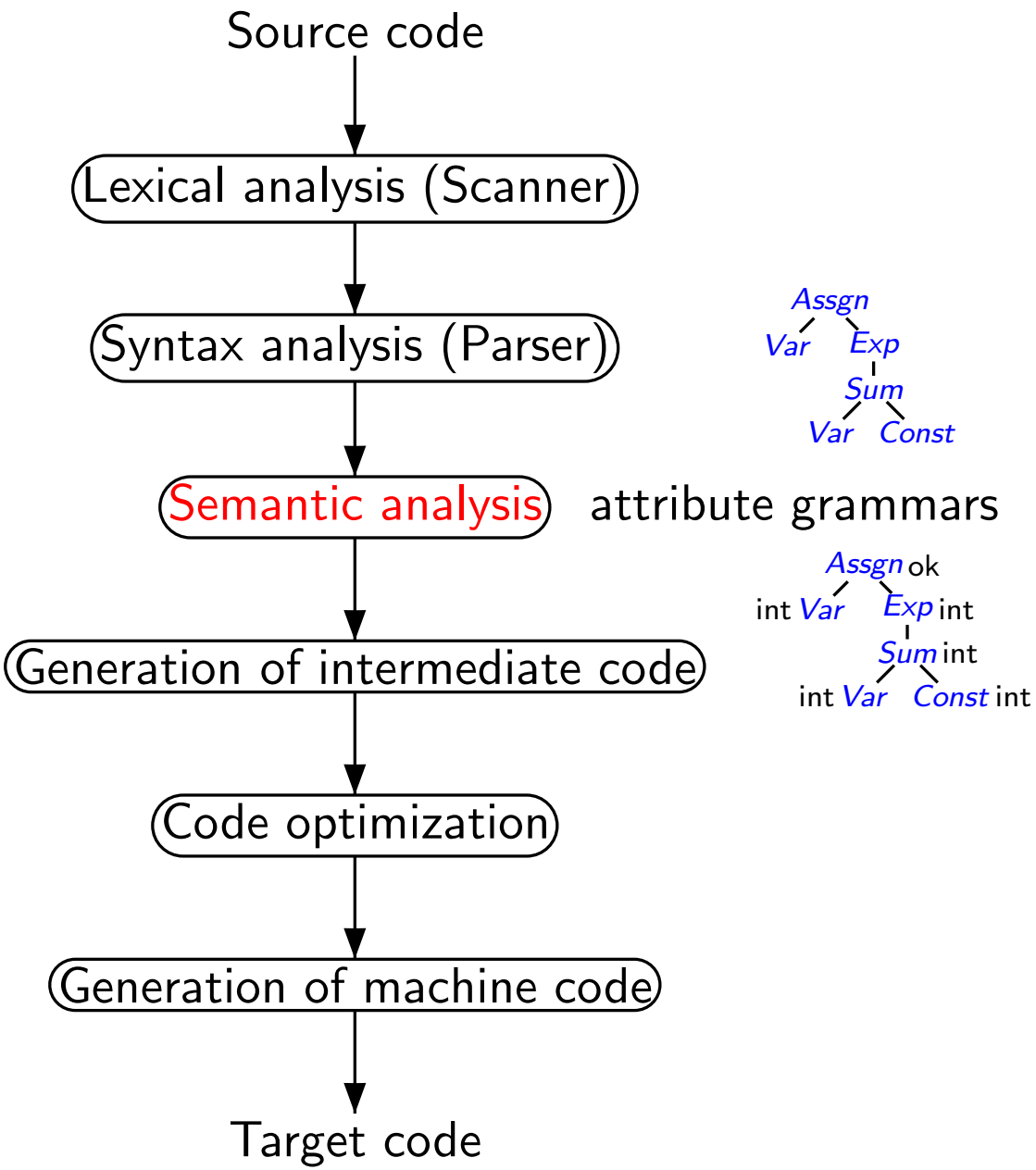

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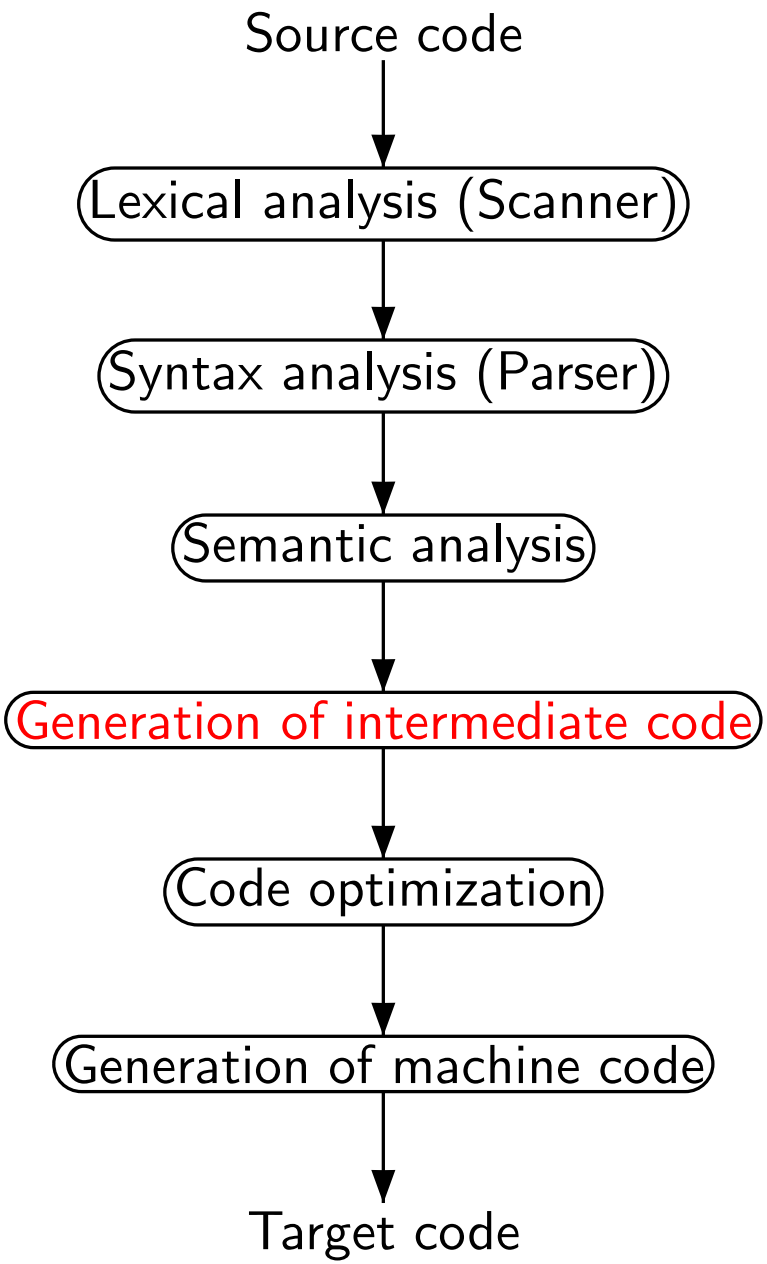

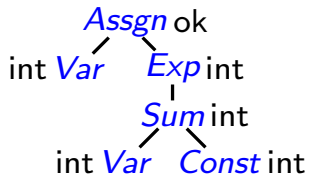

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```
LOAD y2; LIT 1; ADD; STO x1
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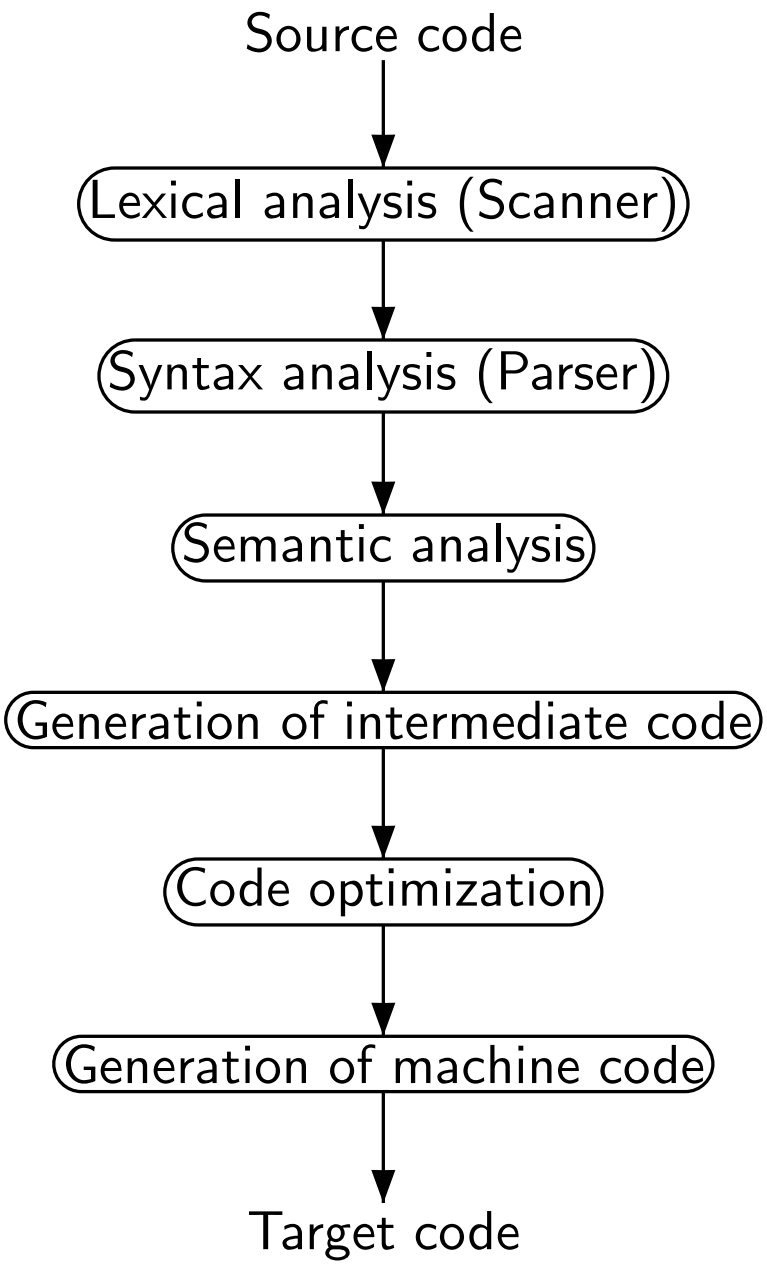


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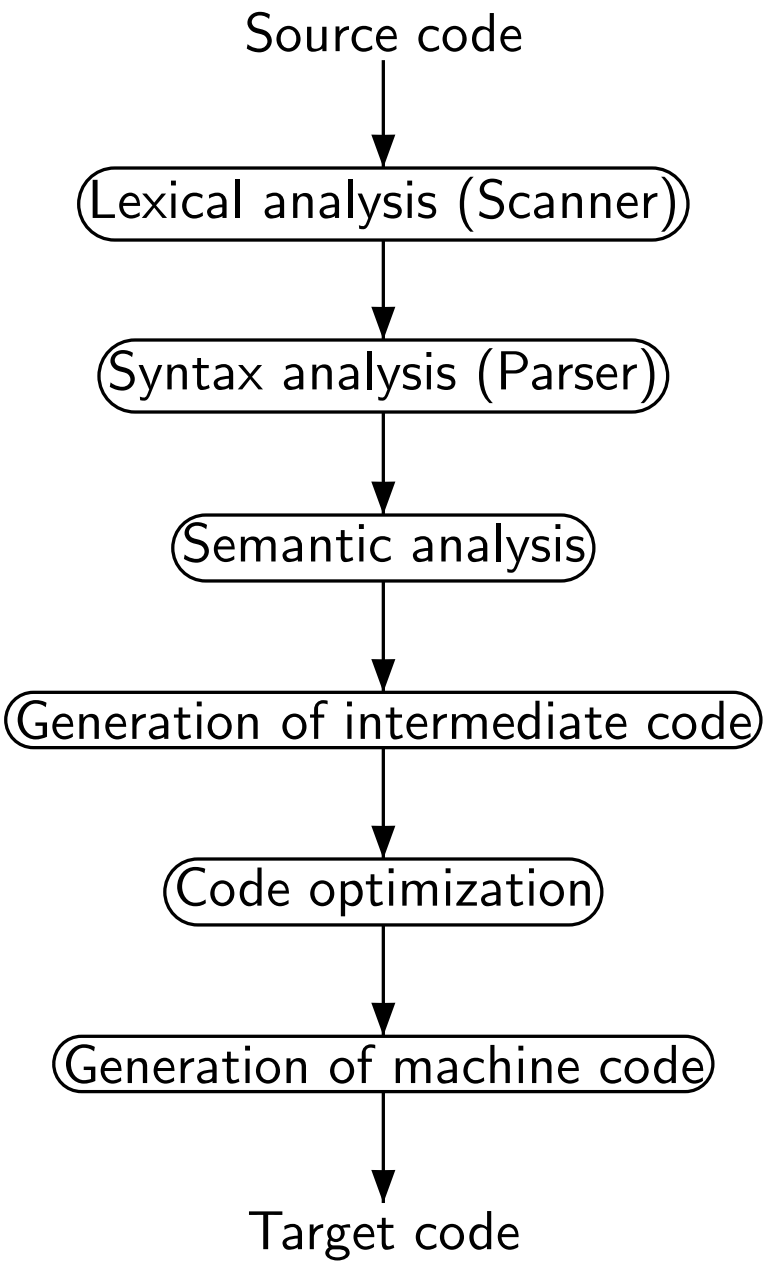

[omitted: symbol table, error handling]

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Historical: *n*-pass compiler

- n = number of runs through source program
- nowadays mainly one-pass

Literature

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General

- A.V. Aho, M.S. Lam, R. Sethi, J.D. Ullman: *Compilers – Principles, Techniques, and Tools; 2nd ed.*, Addison-Wesley, 2007
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