Compiler Construction

Lecture 1: Introduction

Thomas Noll

Lehrstuhl für Informatik 2
(Software Modeling and Verification)

RWTH AACHEN UNIVERSITY

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http://moves.rwth-aachen.de/teaching/ss-14/cc14/

Summer Semester 2014

Outline

People

- Lectures:
  - Thomas Noll (noll@cs.rwth-aachen.de)
- Exercise classes:
  - Friedrich Gretz (fgretz@cs.rwth-aachen.de)
  - Souymodip Chakraborty (chakraborty@cs.rwth-aachen.de)
- Student assistant:
  - Philipp Berger
  - Samiro Discher

Target Audience

- BSc Informatik:
  - Wahlpflicht Theoretische Informatik
- MSc Informatik:
  - Theoretische Informatik
- MSc Software Systems Engineering:
  - Theoretical Foundations of SSE (was: Theoretical CS)

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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- 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
- What we expect: basic knowledge in
  - imperative programming languages
  - algorithms and data structures
  - formal languages and automata theory

Organization

- Schedule:
  - Lecture Mon 14:15–15:45 AH 6 (starting 14 April)
  - Lecture Wed 10:15–11:45 AH 6 (starting 9 April)
  - Exercise class Fri 08:15–09:45 AH 2 (starting 16 April)
  - Special: 16 April (exercise), 2/4 June (itestra)
  - see overview at http://moves.rwth-aachen.de/teaching/ss-14/cc14/

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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

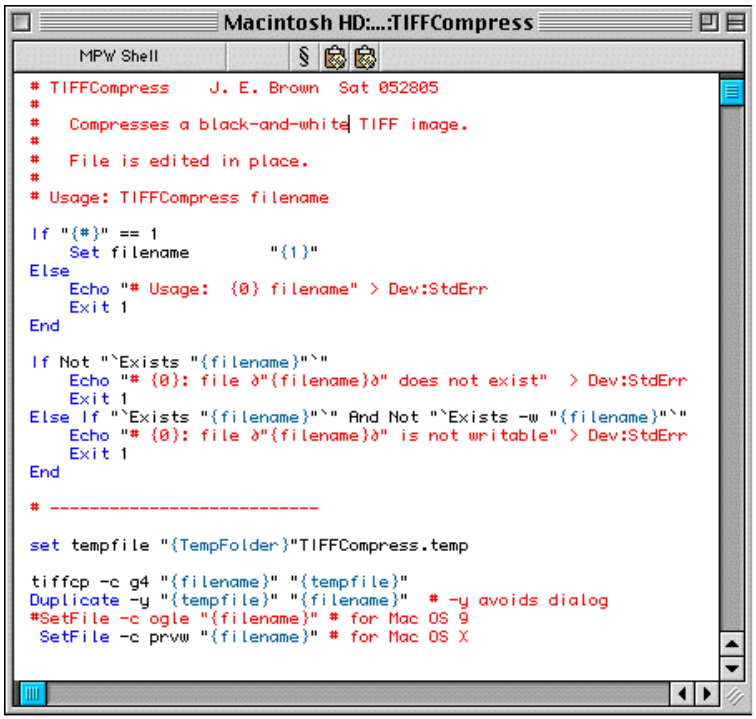
Target code: low-level code, tailored to machine

- platform-independent byte code (for virtual machine such as JVM)
- platform-dependent assembly/machine code (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 also 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 I

Efficiency of generated code

Goal: target code as fast and/or memory efficient as possible

- program analysis and optimization
- cf. course on Static Program Analysis (WS 2012/13, 2014/15)

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Efficiency of compiler

Goal: translation process as fast and/or memory efficient as possible (for inputs of arbitrary size)

- fast (linear-time) algorithms
- sophisticated data structures

Properties of a Good Compiler II

Correctness

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

- compiler validation and verification
- proof-carrying code, ...
- cf. course on Semantics and Verification of Software (SS 2013, 2015)

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Remark: mutual tradeoffs!

Aspects of a Programming Language

Syntax: "How does a program look like?"

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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`
   - `DO 5 K = 1.3`: assignment to (`real`) variable `DO5K`

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

PASCAL: never

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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, ...
- cf. `http://catalog.compilertools.net/`

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- by regular expressions and finite automata

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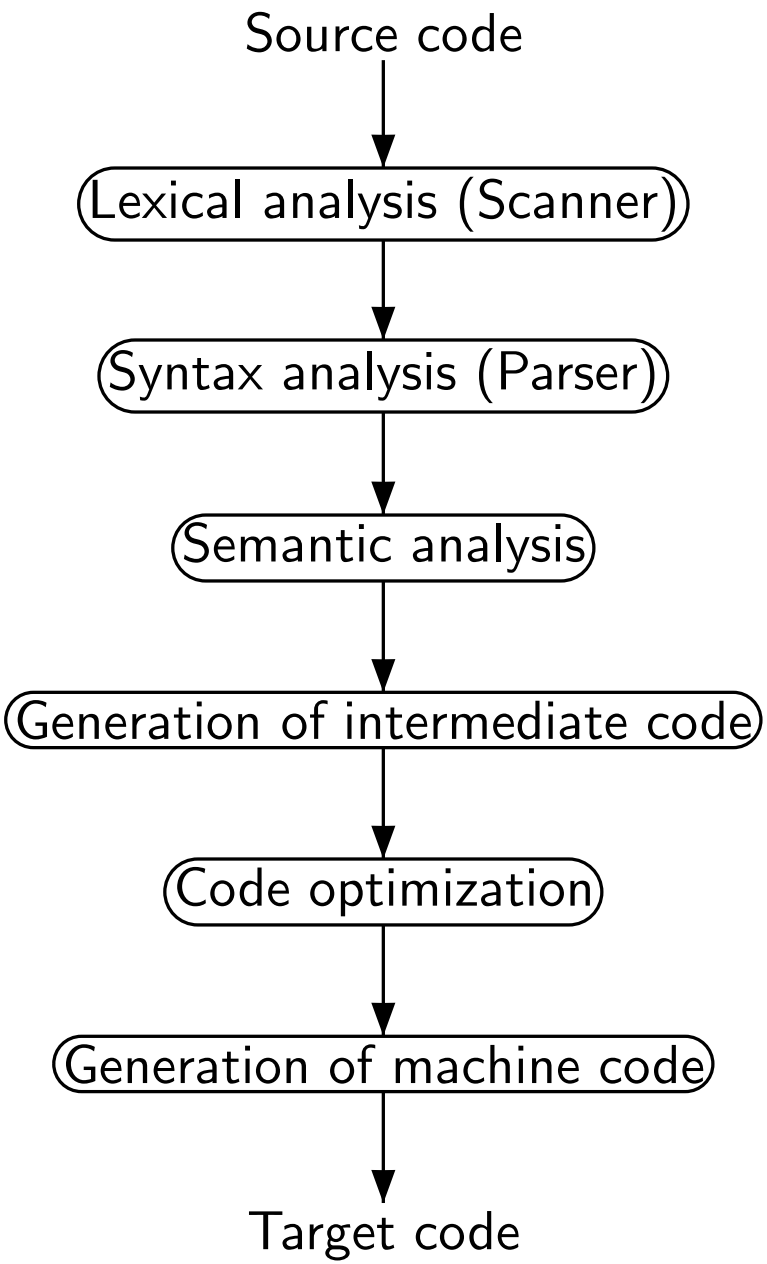
Code optimization: to improve runtime and/or memory behavior

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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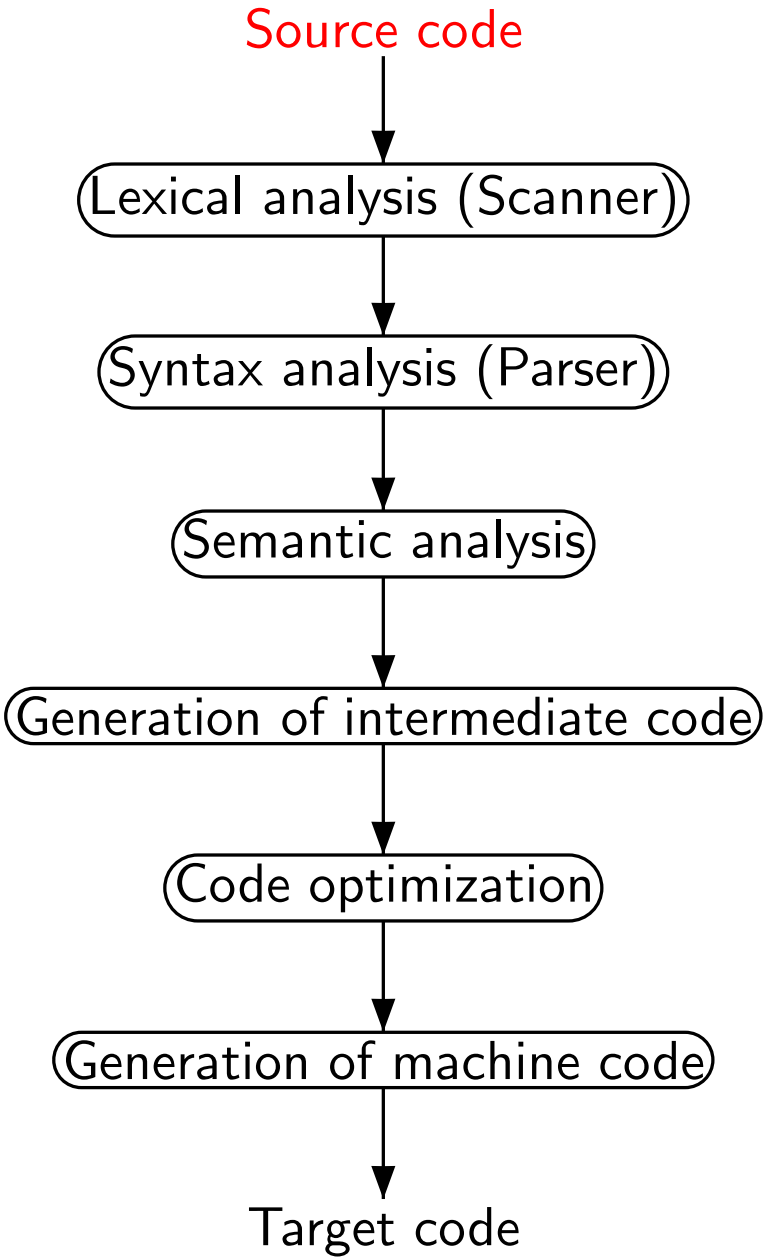


```
x1 := y2 + 1
```

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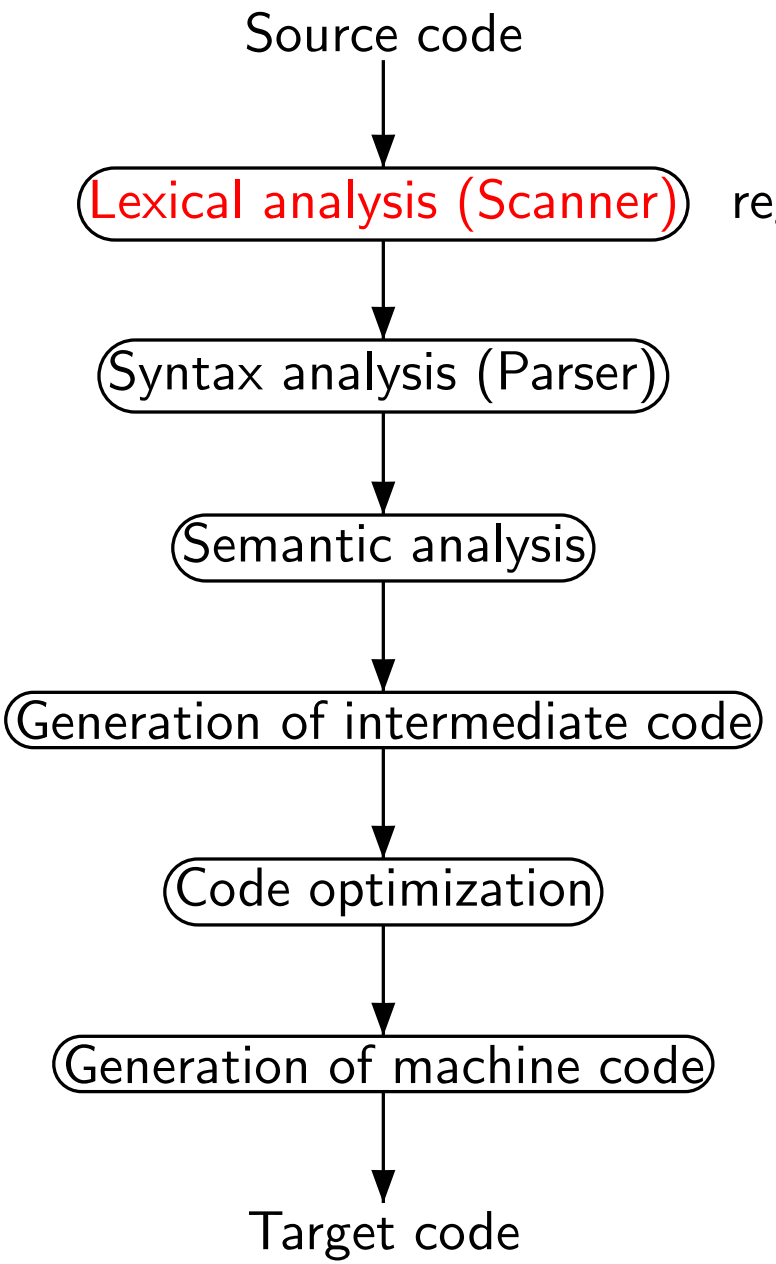

`x1 := y2 + 1`

regular expressions/finite automata

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

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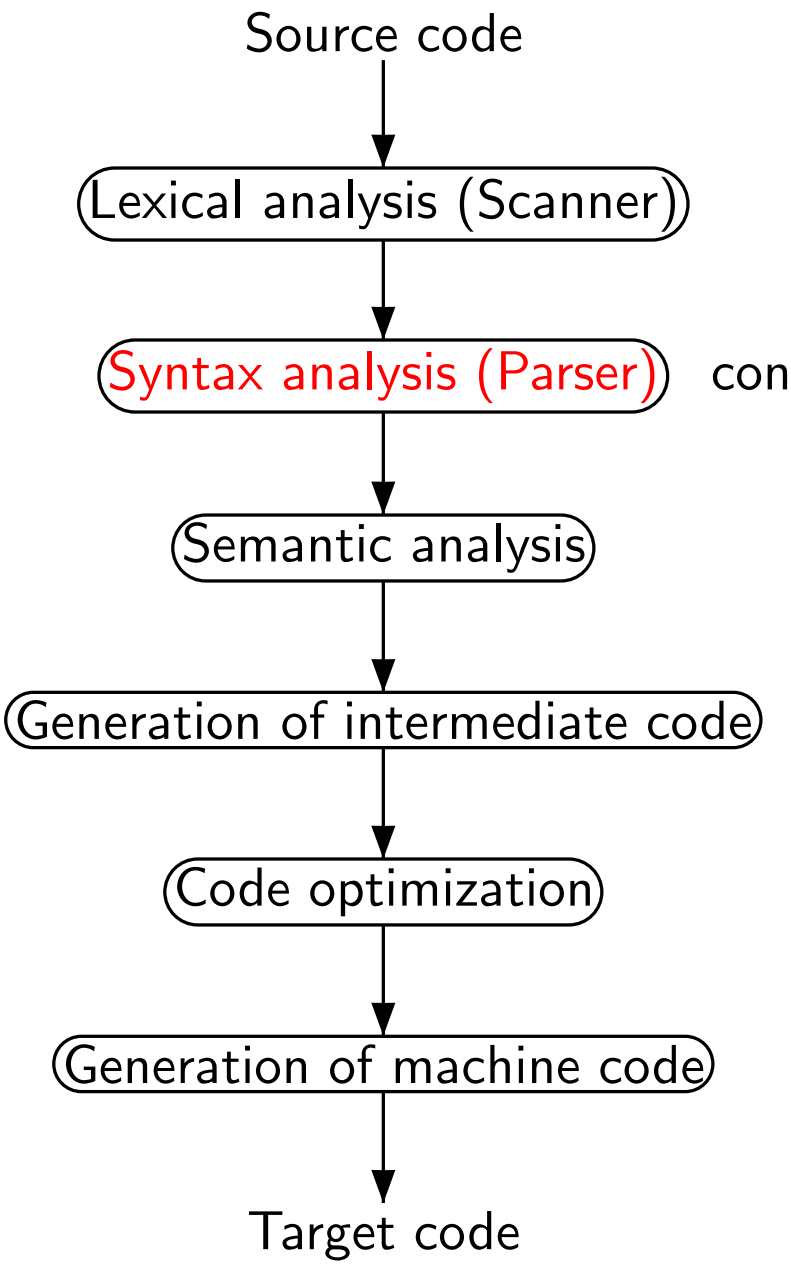

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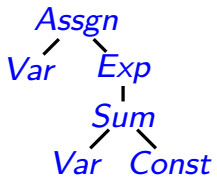
context-free grammars/pushdown automata



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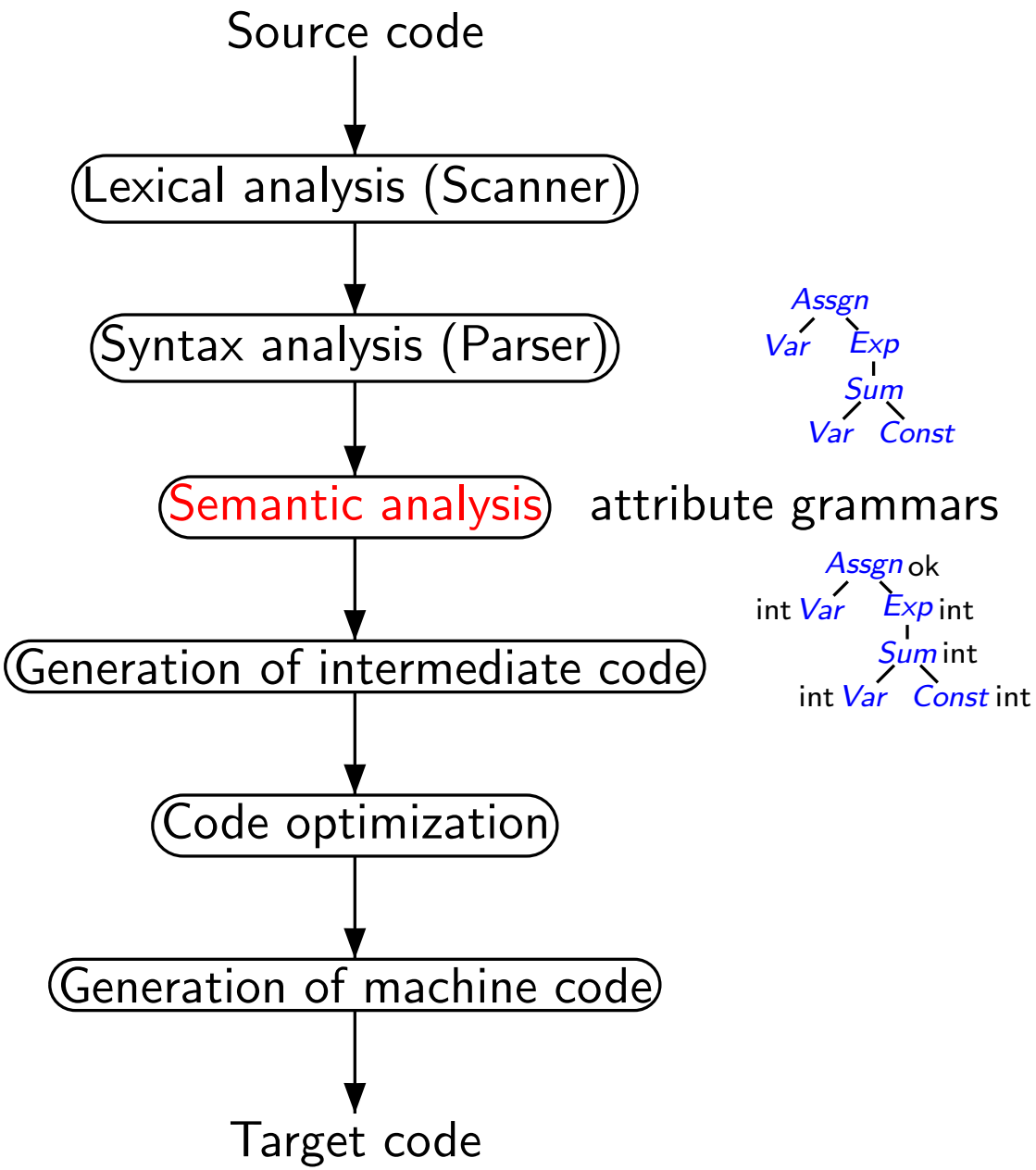

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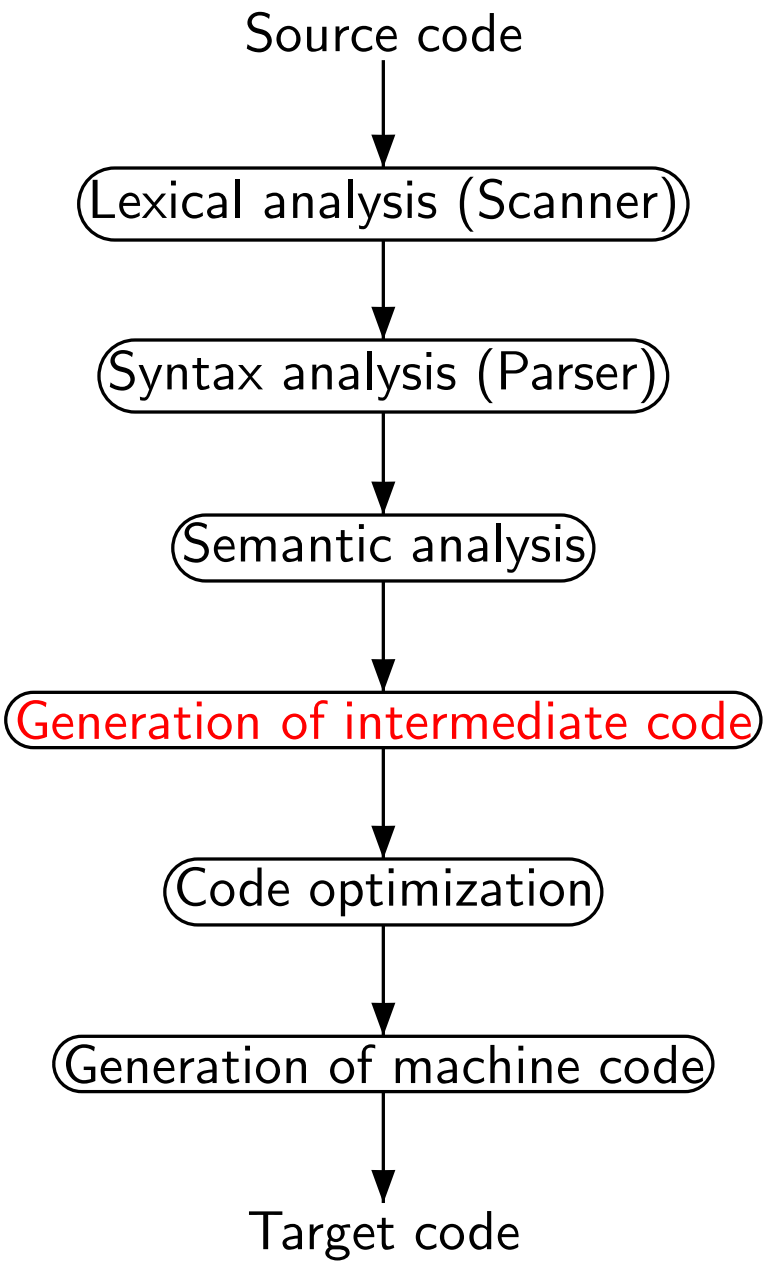

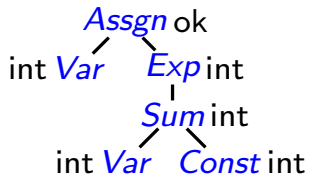

tree translations

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

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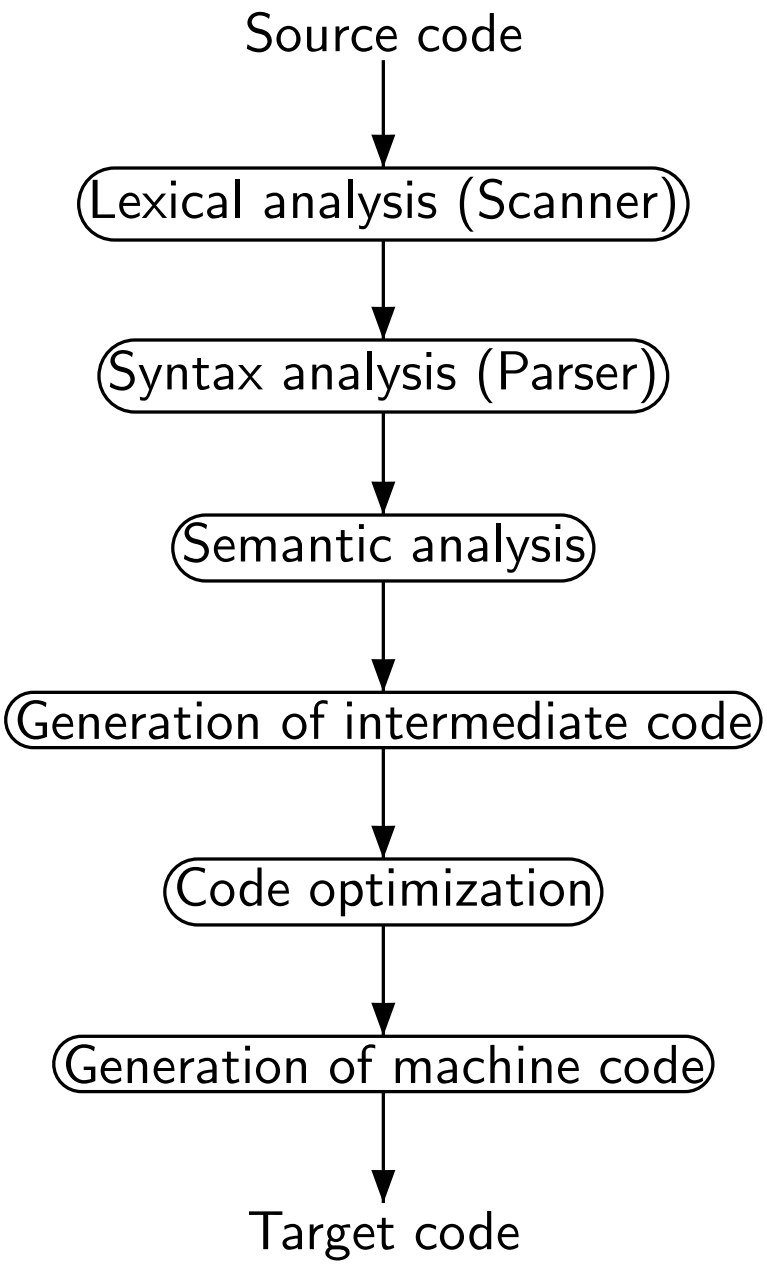


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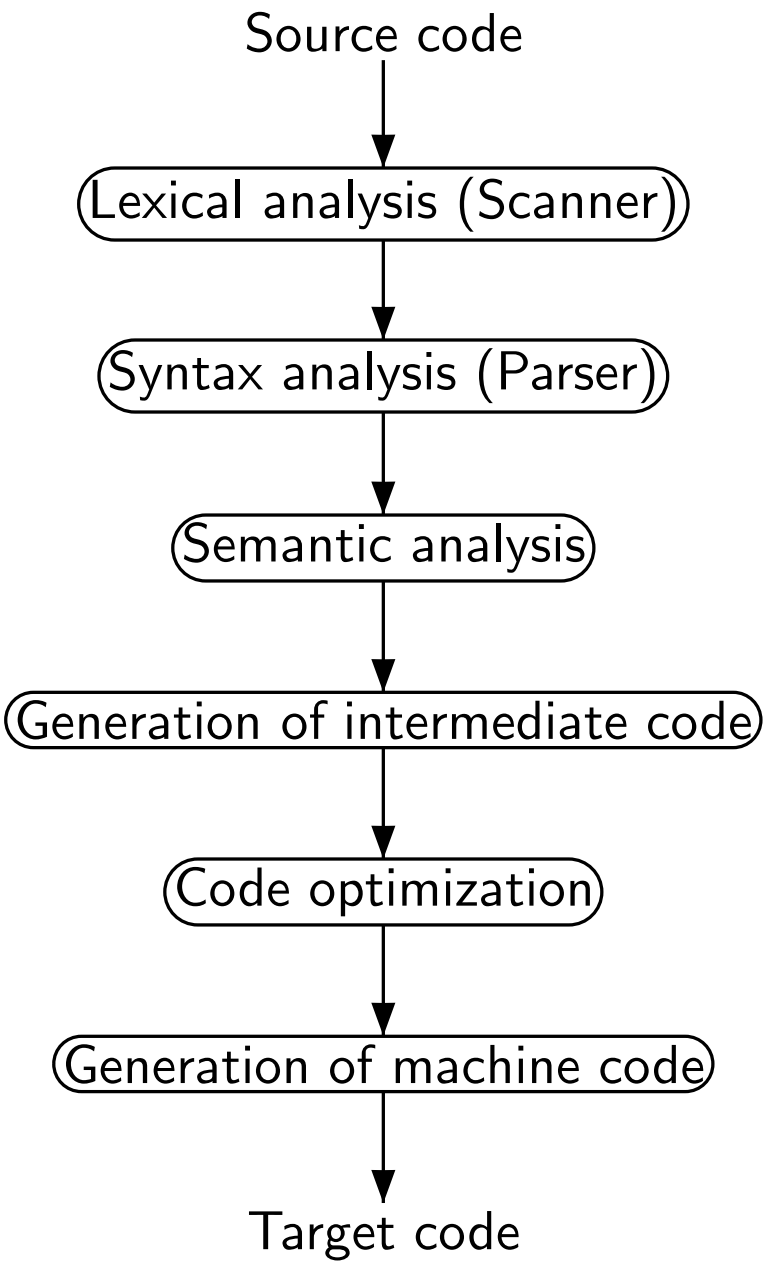

[omitted: symbol table, error handling]

Classification of Compiler Phases

Analysis vs. synthesis

Analysis: lexical/syntax/semantic analysis
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Synthesis: generation of (intermediate/machine) code + optimization

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Historical: *n*-pass compiler

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

Literature

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