Script **generated by TTT**

Title: Petter: Compilerbau (20.04.2015)

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Pages: 51

TECHNISCHE UNIVERSITÄT MÜNCHEN

FAKULTÄT FÜR INFORMATIK

Compiler Construction I

Dr. Michael Petter

SoSe 2015

Organizing

Dates:

Lecture: Mo. 14:15-15:45
Tutorial: You can vote on two dates via moodle

Exam:

- One Exam in the summer, none in the winter
- Exam managed via TUM-online
- Successful (50% credits) tutorial exercises earns 0.3 bonus

Organizing

- Master or Bachelor in the 6th Semester with 5 ECTS
- Prerequisites
  - Informatik 1 & 2
  - Theoretische Informatik
  - Technische Informatik
  - Grundlegende Algorithmen
- Delve deeper with
  - Virtual Machines
  - Programmoptimization
  - Programming Languages
  - Praktikum Compilerbau
  - Seminars

Materials:

- TTT-based lecture recordings
- the slides
- Related literature list online (⇒ Wilhelm/Seidl/Hack Compiler Design)
- Tools for visualization of virtual machines (VAM)
- Tools for generating components of Compilers (JFlex/CUP)

Preliminary content

- Basics in regular expressions and automata
- Specification and implementation of scanners
- Reduced context free grammars and pushdown automata
- Bottom-Up Syntaxanalysis
- Attribute systems
- Typechecking
- Codegeneration for ~~stack~~ registers machines
- Register assignment
- Basic Optimization

Topic:

Introduction

Interpreter

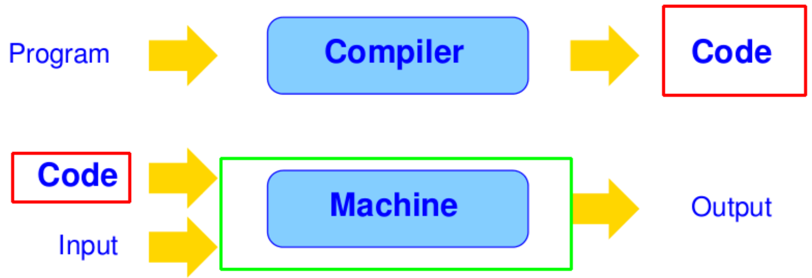
Pro:

No precomputation on program text necessary
⇒ no/small Startup-time

Con:

Program components are analyzed multiple times during the execution
⇒ longer runtime

Concept of a Compiler



Two Phases:

1. Translating the program text into a machine code
2. Executing the machine code on the input

Compiler

A precomputation on the program allows

- a more sophisticated variable management
- discovery and implementation of global optimizations

Disadvantage

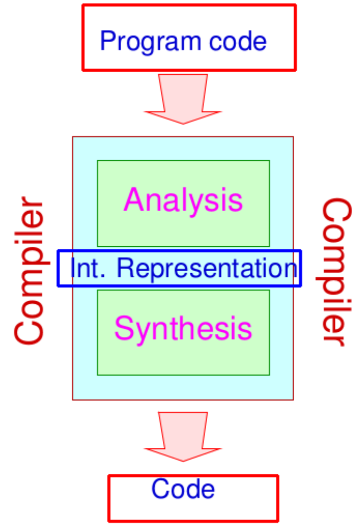
The Translation costs time

Advantage

The execution of the program becomes more efficient
⇒ payoff for more sophisticated or multiply running programs.

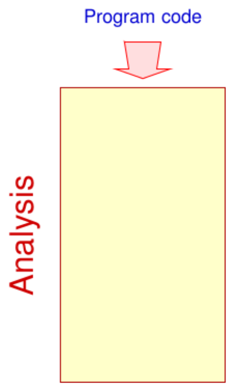
Compiler

general Compiler setup:



Compiler

The Analysis-Phase is divided in several parts:



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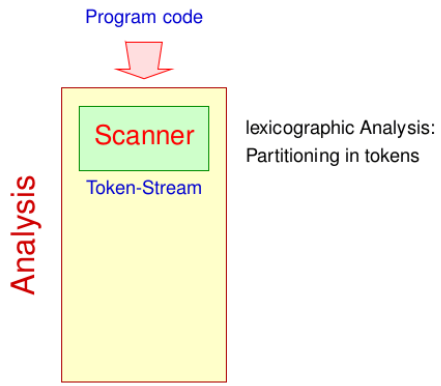

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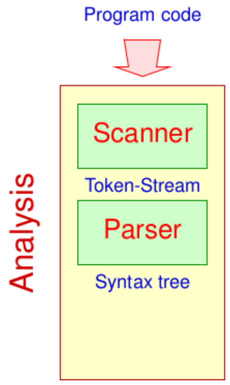

lexicographic Analysis:
Partitioning in tokens

syntactic Analysis:
Detecting hierarchical structure

Compiler

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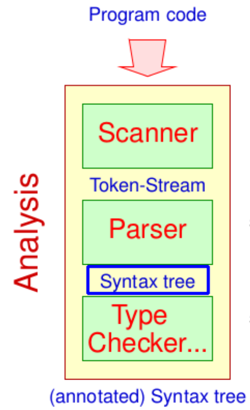

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syntactic Analysis:
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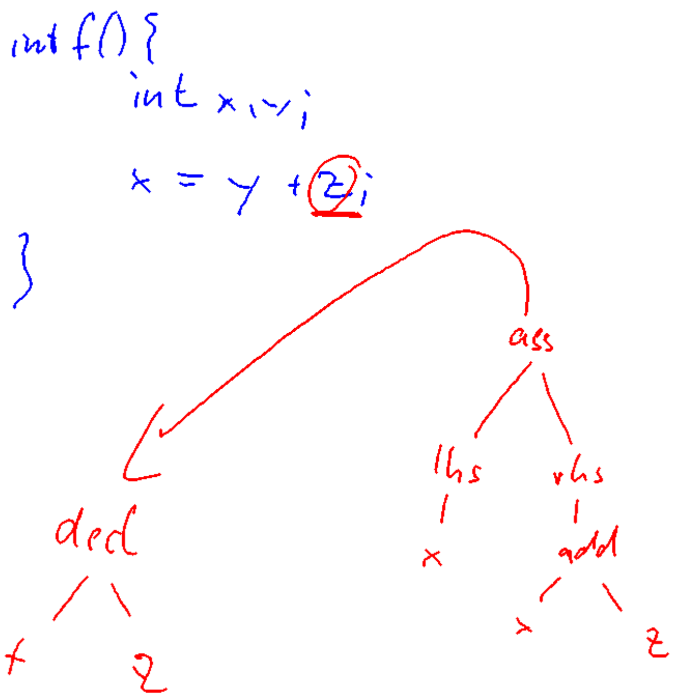
semantic Analysis:
Infering semantic properties



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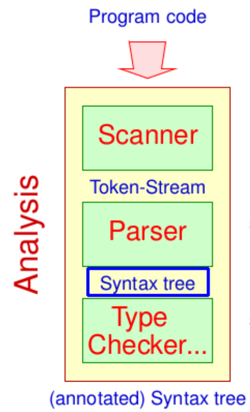

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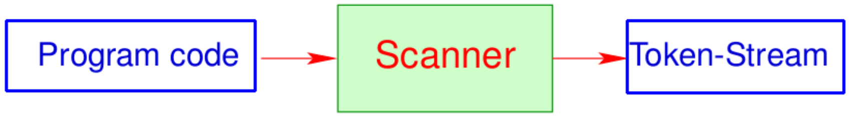
The lexical Analysis



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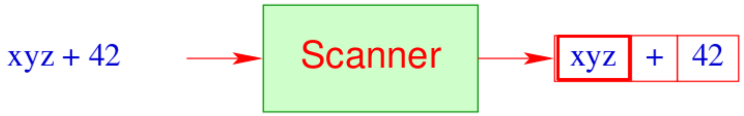

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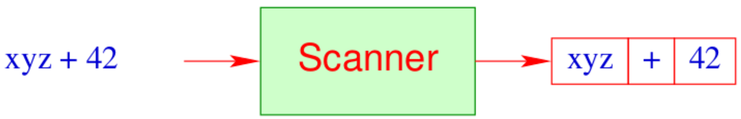

- A Token is a sequence of characters, which together form a unit.
- Tokens are subsumed in classes. For example:
  - → Names (Identifiers) e.g. `xyz`, `pi`, ...
  - → Constants e.g. `42`, `3.14`, `"abc"`, ...
  - → Operators e.g. `+`, ...
  - → reserved terms e.g. `if`, `int`, ...

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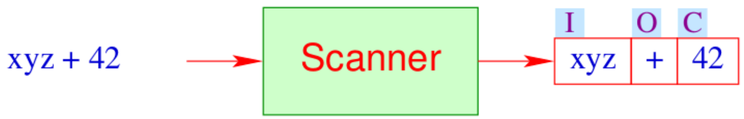

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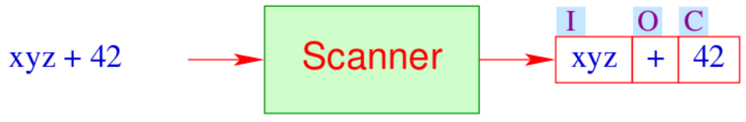
The Lexical Analysis

Classified tokens allow for further pre-processing:

- Dropping irrelevant fragments e.g. Spacing, Comments,...
- Separating Pragmas, i.e. directives vor the compiler, which are not directly part of the program, like include-Statements;
- Replacing of Tokens of particular classes with their meaning / internal representation, e.g.
  - → Constants;
  - → Names: typically managed centrally in a Symbol-table, evt. compared to reserved terms (if not already done by the scanner) and possibly replaced with an index.

⇒ Siever

The lexical Analysis



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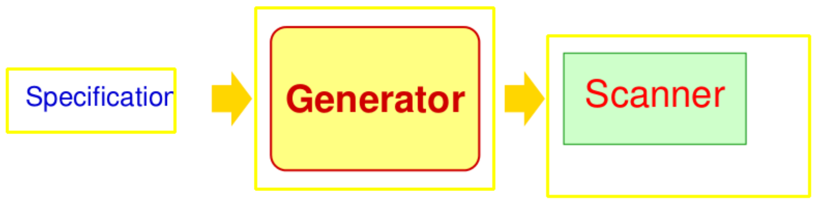
The Lexical Analysis

Discussion:

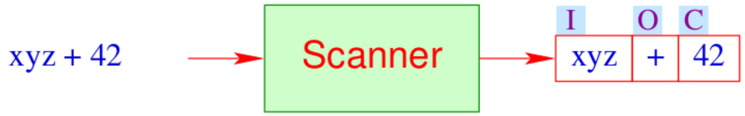
- Scanner and Siever are often combined into a single component, mostly by providing appropriate callback actions in the event that the scanner detects a token.
- Scanners are mostly not written manually, but generated from a specification.



The Lexical Analysis - Generating:

... in our case:

The lexical Analysis



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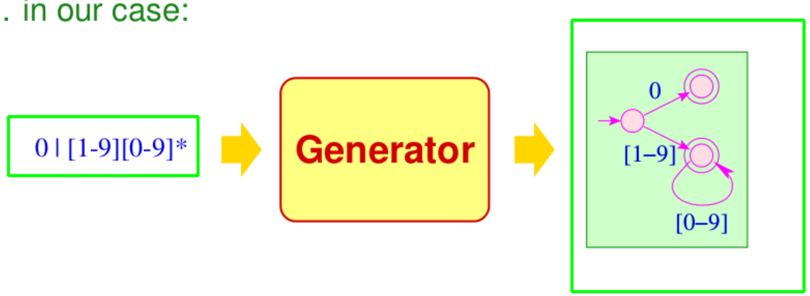

Specification of Token-classes: Regular expressions;

Generated Implementation: Finite automata + X

Chapter 1:
Basics: Regular Expressions

Regular Expressions

Basics

- Program code is composed from a finite alphabet Σ of input characters, e.g. Unicode
- The sets of textfragments of a token class is in general regular.
- Regular languages can be specified by regular expressions.

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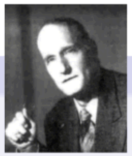
Stephen Kleene

Definition Regular Expressions

The set $\mathcal{E}_\Sigma$ of (non-empty) regular expressions is the smallest set $\mathcal{E}$ with:

- $\epsilon \in \mathcal{E}$ (ϵ a new symbol not from Σ);
- $a \in \mathcal{E}$ for all $a \in \Sigma$;
- $(e_1 \mid e_2), (e_1 \cdot e_2), e_1^* \in \mathcal{E}$ if $e_1, e_2 \in \mathcal{E}$.

Regular Expressions

... Example:

$((a \cdot b^*) \cdot a)$
$(a \mid b)$
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Attention:

- We distinguish between characters $a, 0, \$,$... and Meta-symbols $(, |,)$,...
- To avoid (ugly) parantheses, we make use of Operator-Precedences:

$$^* > \cdot > |$$

and omit "$\cdot$"

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- To avoid (ugly) parantheses, we make use of Operator-Precedences:

$$^* > \cdot > |$$

and omit "$\cdot$"
- Real Specification-languages offer additional constructs:

$$e? \equiv (\epsilon \mid e)$$
$$e^+ \equiv (e \cdot e^*)$$

and omit "ϵ"

Regular Expressions

Specifications need Semantics
...Example:

Specification	Semantics
$abab$	$\{abab\}$
$a \mid b$	$\{a, b\}$
ab^*a	$\{ab^na \mid n \geq 0\}$

For $e \in \mathcal{E}_\Sigma$ we define the specified language $[\![e]\!] \subseteq \Sigma^*$ inductively by:

$$[\![\epsilon]\!] = \{\epsilon\}$$
$$[\![a]\!] = \{a\}$$
$$[\![e^*]\!] = ([\![e]\!])^*$$
$$[\![e_1|e_2]\!] = [\![e_1]\!] \cup [\![e_2]\!]$$
$$[\![e_1 \cdot e_2]\!] = [\![e_1]\!] \cdot [\![e_2]\!]$$

Keep in Mind:

- The operators $(\_)^*, \cup, \cdot$ are interpreted in the context of sets of words:

$$(L)^* = \{w_1 \ldots w_k \mid k \geq 0, w_i \in L\}$$
$$L_1 \cdot L_2 = \{w_1 w_2 \mid w_1 \in L_1, w_2 \in L_2\}$$

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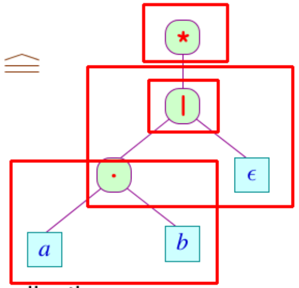
- Regular expressions are internally represented as annotated ranked trees:

$(ab|\epsilon)^* \quad \widehat{=}$



Inner nodes: Operator-applications;
Leaves: particular symbols or ϵ.

Regular Expressions

Example: Identifiers in Java:

```
le = [a-zA-Z_\$]
di = [0-9]
Id = {le} ({le} | {di})*
```


Regular Expressions

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le = [a-zA-Z_\$]
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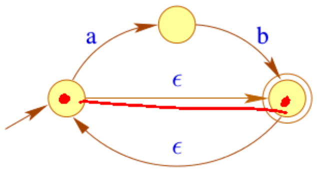
Float = {di}* (\.{di}|{di}\.) {di}*((e|E)(\+|\-)?{di}+)?
```

.9e+80

Chapter 2:
Basics: Finite Automata

Finite Automata

Example:



Finite Automata


Michael Rabin


Dana Scott

Definition Finite Automata

A non-deterministic finite automaton (NFA) is a tuple $A = (Q, \Sigma, \delta, I, F)$ with:

Q	a finite set of states;
Σ	a finite alphabet of inputs;
$I \subseteq Q$	the set of start states;
$F \subseteq Q$	the set of final states and
δ	the set of transitions (-relation)

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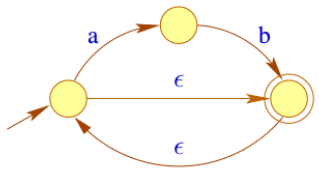
For an NFA, we reckon:

Definition Deterministic Finite Automata

Given $\delta : Q \times \Sigma \to Q$ a function and $|I| = 1$, then we call the NFA A deterministic (DFA).

Finite Automata

- Computations are paths in the graph.
- Accepting computations lead from I to F.
- An accepted word is the sequence of lables along an accepting computation ...



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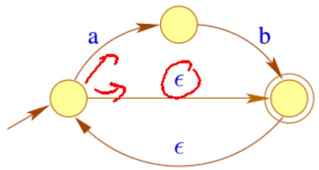

Nodes: States;
Edges: Transitions;
Lables: Consumed input;

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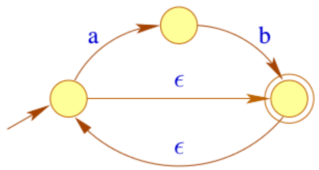

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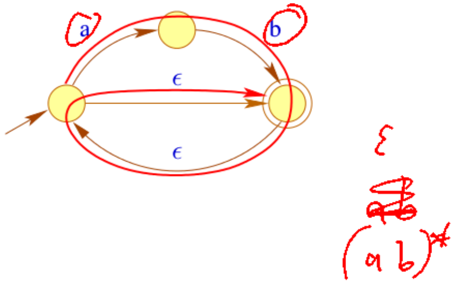


Finite Automata

Once again, more formally:

- We define the transitive closure δ^* of δ as the smallest set δ' with:

  $(p, \epsilon, p) \in \delta'$ and
  $(p, xw, q) \in \delta'$ if $(p, x, p_1) \in \delta$ and $(p_1, w, q) \in \delta'$.

  δ^* characterizes for two states p and q the words, along each path between them

- The set of all accepting words, i.e. A's accepted language can be described compactly as:

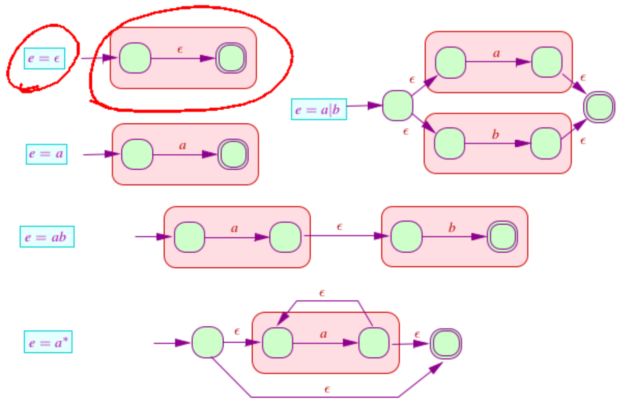
$$\mathcal{L}(A) = \{w \in \Sigma^* \mid \exists i \in I, f \in F : (i, w, f) \in \delta^*\}$$

Lexical Analysis

Chapter 3:

Converting Regular Expressions to NFAs

In linear time from Regular Expressions to NFAs



Ken Thompson

Thompson's Algorithm

Produces $\mathcal{O}(n)$ states for regular expressions of length n.