Programming Languages and Compilers

Prof. Dr. Uwe Kastens

WS 2013 / 2014

0. Introduction

Objectives

The participants are taught to

- understand properties and notions of programming languages
- understand **fundamental techniques** of language implementation, and to use **generating tools and standard solutions**,
- apply compiler techniques for design and implementation of **specification languages and domain specific languages**

Forms of teaching:

Lectures

Tutorials

Homeworks

Exercises

Running project

Contents

Prerequisites

from Lecture	Topic	here needed for
Foundations of Programming Languages:		
	4 levels of language properties	Language specification, compiler tasks
	Context-free grammars	Grammar design, syntactic analysis
	Scope rules	Name analysis
	Data types	Type specification and analysis
Modeling:		
	Finite automata	Lexical analysis
	Context-free grammars	Grammar design, syntactic analysis

References

Material for this course **PLaC**: http://ag-kastens.upb.de/lehre/material/plac
for the Master course **Compilation Methods**: http://ag-kastens.upb.de/lehre/material/compii

Modellierung: http://ag-kastens.upb.de/lehre/material/model
Grundlagen der Programmiersprachen: http://ag-kastens.upb.de/lehre/material/gdp

John C. Mitchell: **Concepts in Programming Languages**, Cambridge University Press, 2003

R. W. Sebesta: **Concepts of Programming Languages**, 4. Ed., Addison-Wesley, 1999

U. Kastens: **Übersetzerbau**, Handbuch der Informatik 3.3, Oldenbourg, 1990
(not available on the market anymore, available in the library of the University)

A. W. Appel: **Modern Compiler Implementation in Java**, Cambridge University Press, 2nd Edition, 2002 (available for C and for ML, too)

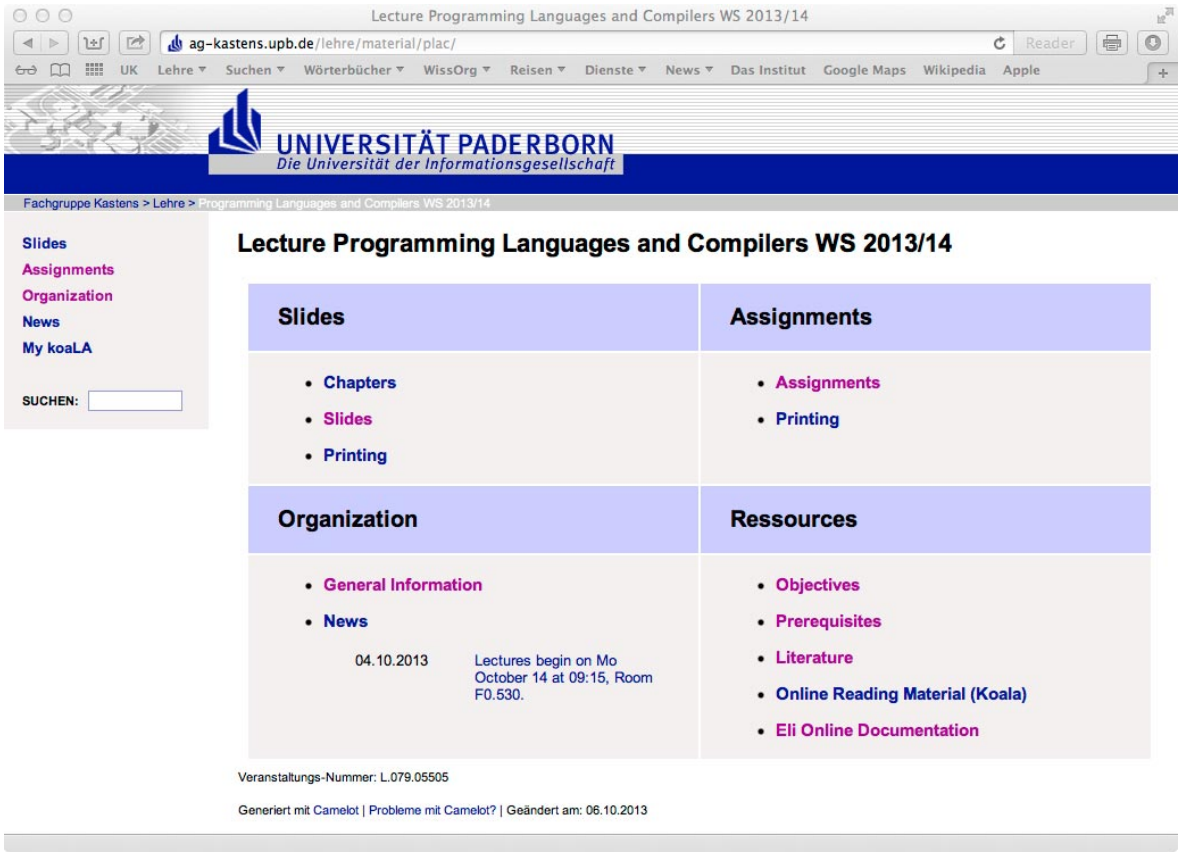
W. M. Waite, L. R. Carter: **An Introduction to Compiler Construction,** Harper Collins, New York, 1993

U. Kastens, A. M. Sloane, W. M. Waite: **Generating Software from Specifications**, Jones and Bartlett Publishers, 2007

References forReading

Week	Chapter	Kastens	Waite Carter	Eli Doc.
1	0. Introduction			
2	1. Language Properties and Compiler tasks	1, 2	1.1 - 2.1	
3 - 4	2. Symbol Specification and Lexical Analysis	3	2.4 3.1 - 3.3	+
5 - 7	3. Context-free Grammars and Syntactic Analysis	4	4, 5, 6	+
8 - 10	4. Attribute Grammars and Semantic Analysis	5		+
11	5. Binding of Names	6.2	7	+
12	6. Type Specification and Analysis	(6.1)		+
13	7. Specification of Dynamic Semantics			
13	8. Source-to-Source Translation			
	9. Domain Specific Languages			

Course material in the Web



Commented slide in the course material

Programming Languages and Compilers WS 2012/13 - Slide 009

PLaC-0.9

What does a compiler compile?

A **compiler** transforms correct sentences of its **source language** into sentences of its **target language** such that their **meaning is unchanged.** Examples:

Source language:	Target language:
Programming language C++	**Machine language** Sparc code
Programming language Java	**Abstract machine** Java Bytecode
Programming language C++	**Programming language (source-to-source)** C
Domain specific language LaTeX, Data base language (SQL)	**Application language** HTML, Data base system calls
Application generator: **Domain specific language** SIM Toolkit language	**Programming language** Java

Some languages are **interpreted** rather than compiled:
Lisp, Prolog, Script languages like PHP, JavaScript, Perl

Objectives:
Variety of compiler applications

In the lecture:
Explain examples for pairs of source and target languages.

Suggested reading:
Kastens / Übersetzerbau, Section 1.

Assignments:

- Find more examples for application languages.
- Exercise 3 Recognize patterns in the target programs compiled from simple source programs.

Questions:
What are reasons to compile into other than machine languages?

Organization of the course

Programming Languages and Compilers WS 2013/14 - Organization

Lecturer

Prof. Dr. Uwe Kastens:

Office Hours

- Wed 16.00 - 17.00 F2.308
- Tue 11.00 - 12.00 F2.308

Hours

Lecture

- V2 Mo 09.15 - 10.45, F0.530

Start date: Oct 14, 2013

Excercises

- Ü1 Mo 11.00 - 11.45, F0.530 / F1.520

Start date: Oct 14, 2013

Examination

Oral examinations of 20 to 30 min duration. Any topic of the lecture and of the tutorial may be subject of the exam. See also the sequence of questions in Chapter 10.

Two time spans are offered for examinations:

1. Feb 12 to 14 in 2014
2. April 01 to 03 in 2014

Register in PAUL for the one or the other time span; then ask for an appointment by email to my secretary Mrs. Gundelach (sigu@upb.de).

Assignments

- Assignments will be published every week.

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Application generator:

Domain specific language	**Programming language**
SIM Toolkit language	Java

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What is compiled here?

```
 class Average
     { private:
         int sum, count;
       public:
         Average (void)
           { sum = 0; count = 0; }
         void Enter (int val)
           { sum = sum + val; count++; }
         float GetAverage (void)
           { return sum / count; }
     };
--------------
_Enter__7Averagei:
             pushl %ebp
             movl %esp,%ebp
             movl 8(%ebp),%edx
             movl 12(%ebp),%eax
             addl %eax,(%edx)
             incl 4(%edx)
     L6:
             movl %ebp,%esp
             popl %ebp
             ret
```

```
class Average
{ private
    int sum, count;
  public
    Average ()
      { sum = 0; count = 0; }
    void Enter (int val)
      { sum = sum + val; count++; }
    float GetAverage ()
      { return sum / count; }
};
---------------
1: Enter: (int) --> void
   Access: []
   Attribute 'Code' (Length 49)
      Code: 21 Bytes Stackdepth: 3 Locals: 2
      0:    aload_0
      1:    aload_0
      2:    getfield cp4
      5:    iload_1
      6:    iadd
      7:    putfield cp4
      10:   aload_0
      11:   dup
      12:   getfield cp3
      15:   iconst_1
      16:   iadd
```


What is compiled here?

```
 program Average;
       var sum, count: integer;
           aver: integer;
       procedure Enter (val: integer);
           begin sum := sum + val;
                 count := count + 1;
           end;
     begin
       sum := 0; count := 0;
       Enter (5); Enter (7);
       aver := sum div count;
     end.
-----------
void ENTER_5 (char *slnk , int VAL_4)
     {
     {/* data definitions: */
        /* executable code: */
        {
           SUM_1 = (SUM_1)+(VAL_4);
           COUNT_2 = (COUNT_2)+(1);
           ;
        }
     }}/* ENTER_5 */
```

```
\documentstyle[12pt]{article}
\begin{document}
\section{Introduction}
This is a very short document.
It just shows
\begin{itemize}
\item an item, and
\item another item.
\end{itemize}
\end{document}

-------------

%%Page: 1 1
1 0 bop 164 315 a Fc(1)81
b(In)n(tro)r(duction)
164 425 y Fb(This)16
b(is)g(a)h(v)o(ery)e(short)
i(do)q(cumen)o(t.)j(It)c(just)g
(sho)o(ws)237 527 y Fa(\017)24 b
Fb(an)17 b(item,)
c(and)237 628 y Fa(\017)24 b
Fb(another)17 b(item.)
961 2607 y(1)p
eop
```

Languages for specification and modeling

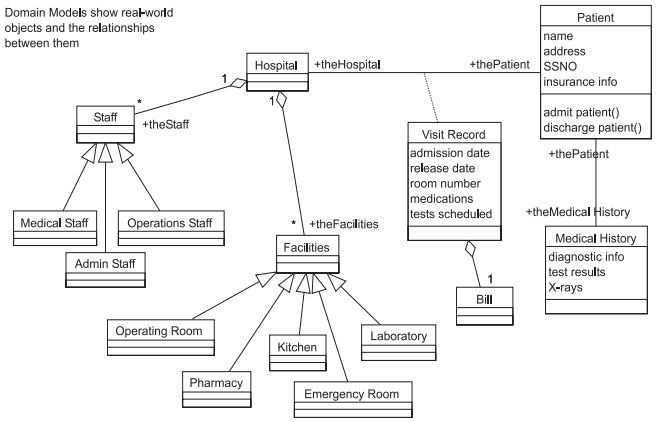
SDL (CCITT)
Specification and Description Language:

```
block Dialogue;
  signal
    Money, Release, Change, Accept, Avail, Unavail, Price,
    Showtxt, Choice, Done, Flushed, Close, Filled;
  process Coins referenced;
  process Control referenced;
  process Viewpoint referenced;
  signalroute Plop
    from env to Coins
      with Coin_10, Coin_50, Coin_100, Coin_x;
  signalroute Pong
    from Coins to env
      with Coin_10, Coin_50, Coin_100, Coin_x;
  signalroute Cash
    from Coins to Control
      with Money, Avail, Unavail, Flushed, Filled;
    from Control to Coins
      with Accept, Release, Change, Close;

  ...

  connect Pay and Plop;
  connect Flush and Pong;
endblock Dialogue;
```

UML
Unified Modeling Language:

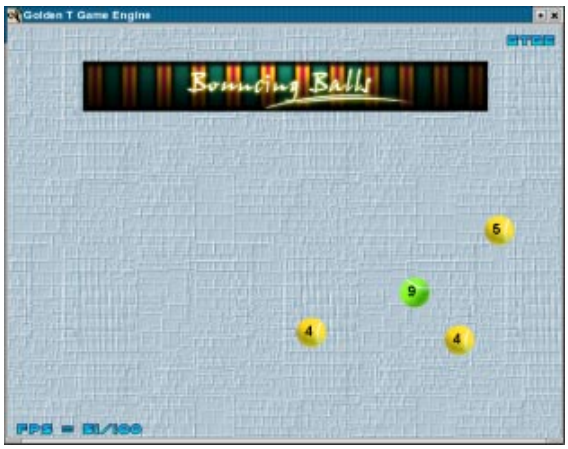


Domain Specific Languages (DSL)

A language designed for a **specific application domain.**
Application Generator: Implementation of a DSL by a **program generator**

Examples:

- **Simulation of mechatronic feedback systems**
- **Robot control**
- **Collecting data from instruments**
- **Testing car instruments**
- **Game description language:**




```
game BBall
{  size 640 480;
   background "pics/backgroundbb.png";
   Ball einball; int ballsize;

   initial {
      ballsize=36;
   }

  events {
      pressed SPACE:
      { einball = new Ball(<100,540>, <100,380>);
```

Programming languages as source or target languages

Programming languages as source languages:

- **Program analysis**
  call graphs, control-flow graph, data dependencies,
  e. g. for the year 2000 problem
- **Recognition of structures and patterns**
  e. g. for Reengineering

Programming languages as target languages:

- **Specifications (SDL, OMT, UML)**
- **graphic modeling of structures**
- **DSL, Application generator**

=> Compiler task: Source-to-source compilation

Semester project as running example

SetLan: A Language for Set Computation

SetLan is a domain-specific language for **programming with sets**. Constructs of the the language are dedicated to describe sets and computations using sets. The language allows to define types for sets and variables and expressions of those types. Specific loop constructs allow to iterate through sets. These constructs are embedded in a simple imperative language.

A source-to-source translator **translates SetLan programs into Java** programs.

The SetLan translator is implemented using the methods and tools introduced in this course.

The participants of this course get an implementation of a **sub-language of SetLan as a starting point** for their work towards their individual extension of the language and the implementation.

```
{
   set a, b; int i;
   i = 1;
   a = [i, 3, 5];
   b = [3, 6, 8];
   print a+b; printLn;
   print a*b <= b;
   printLn;
}
```