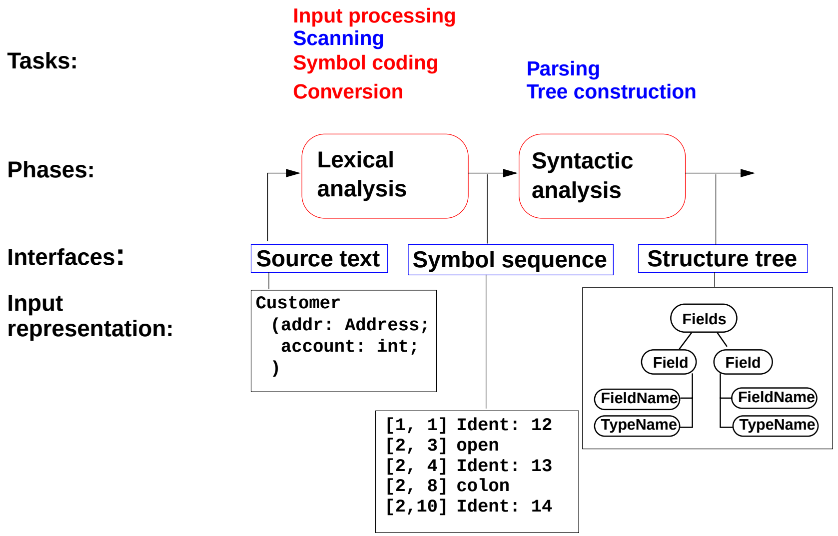
2. Constructing Trees - Overview

Check the notation and the structure of the input and represent it as a tree.



Lecture Generating Software from Specifications WS 2013/14 / Slide 201

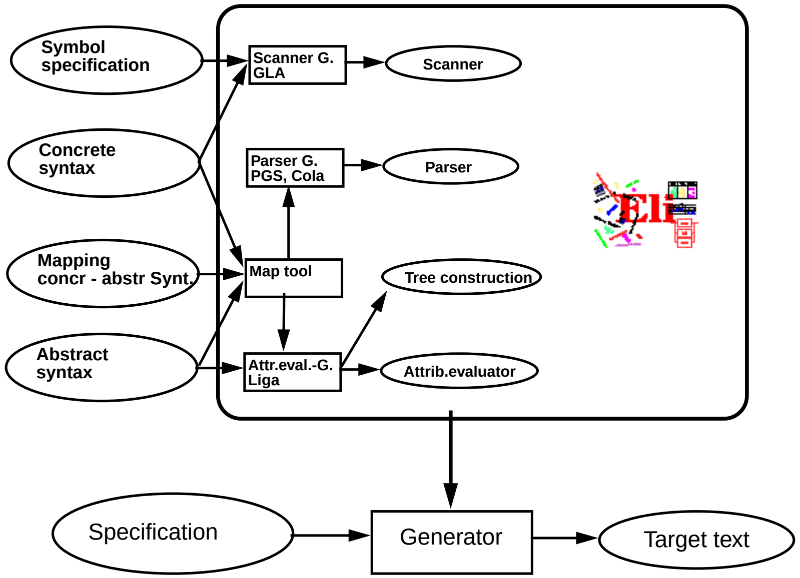
Objectives:

Understand the structuring phase

In the lecture:

- Remember the tasks of GSS-1.15.
- Explain the tasks and representations.

Eli: Specification of the Tree Construction



Lecture Generating Software from Specifications WS 2013/14 / Slide 202

Objectives:

Understand how the structuring phase is generated

In the lecture:

Explain

- Roles of the specifications,
- tasks of the generators,
- cooperation between the generators.

Specifications for the Structure Generator

Symbol specifications

Notations of non-literal tokens
.gla

```
Ident:       PASCAL_IDENTIFIER
FileName:    C_STRING_LIT
             C_COMMENT
```

Concrete syntax

Structure of input,
literal tokens
.con

```
Descriptions:(Import / Structure)*.
Structure:   StructureName '(' Fields ')'.
Fields:      Field*.
Field:       FieldName ':' TypeName.
...
```

Mapping concr - abstr Synt

.map

is empty if concret and abstract syntax coincide

Abstract syntax

Structure of trees
.lido

```
RULE: Descriptions LISTOF Import|Structure
COMPUTE ...

SYMBOL FieldName COMPUTE ...
SYMBOL TypeName COMPUTE ...
```

Only those symbols and productions, which need computations

Objectives:

A simple example

In the lecture:

Get an idea of the specifications

Calendar Example: Structuring Task

A new example for the specification of the structuring task up to tree construction:

Input language: Sequence of calendar entries:

```
1.11.       20:00     "Theater"
Thu         14:15     "GSS lecture"
Weekday     12:05     "Dinner in Palmengarten"
Mon, Thu    8:00      "Dean's office"
31.12.      23:59     "Jahresende"
12/31       23:59     "End of year"
```


Objectives:

Introduce a new example

In the lecture:

Explain the task using the examples

Design of a Concrete Syntax

1. Develop a **set of examples**, such that all aspects of the intended language are covered.
2. Develop a **context-free grammar using a top-down strategy** (see PLaC-3.4aa), and update the set of examples correspondingly.
3. Apply the **design rules** of PLaC-3.4c - 3.4f:
   - Syntactic structure should **reflect semantic structure**
   - **Syntactic restrictions** versus semantic conditions
   - Eliminate **ambiguities**
   - Avoid **unbounded lookahead**
4. Design notations of **non-literal tokens**.

Objectives:

Issues of grammar design

In the lecture:

- The strategy is explained.
- Repeat the methods learned in PLaC Sect. 3.2

Concrete Syntax

specifies the **structure of the input** by a context-free grammar:

```
Calendar:        Entry+ .
Entry:           Date Event.

Date:            DayNum '.' MonNum '.' /
                 MonNum '/' DayNum /
                 DayNames / GeneralPattern.

DayNum:          Integer.
MonNum:          Integer.

DayNames:        DayName /
                 DayNames ',' DayName.
DayName:         Day.

GeneralPattern:  SimplePattern /
                 SimplePattern Modifier.
SimplePattern:   'Weekday' / 'Weekend'.
Modifier:        '+' DayNames / '-' DayNames.

Event:           When Description / Description.

When:            Time / Time '-' Time.
```

Notation:

- Sequence of productions
- literal terminals between '
- EBNF constructs:
  / alternative
  ( ) parentheses
  [ ] option
  +, * repetition
  // repetition with separator

(for meaning see GPS)

Example:

```
1.11.       20:00     "Theater"
Thu         14:15     "GSS lecture"
Weekday     12:05     "Dinner in Palmengarten"
Mon, Thu    8:00      "Dean's office"
31.12.      23:59     "Jahresende"
12/31       23:59     "End of year"
```


Objectives:

Learn the CFG notation

In the lecture:

- Design of productions,
- notation of productions,
- relate to example input.

Literal and Non-Literal Terminals

Definition of notations of

- literal terminals (unnamed): **in the concrete syntax**
- non-literal terminals (named): in an additional **specification for the scanner generator**

```
Calendar:        Entry+ .
Entry:           Date Event.
Date:            DayNum '.' MonNum '.' /
                 MonNum '/' DayNum /
                 DayNames / GeneralPattern.
DayNum:          Integer.
MonNum:          Integer.
DayNames:        DayName /
                 DayNames ',' DayName.
DayName:         Day.
GeneralPattern:  SimplePattern /
                 SimplePattern Modifier.
SimplePattern:   'Weekday' / 'Weekend'.
Modifier:        '+' DayNames / '-' DayNames.
Event:           When Description / Description.
When:            Time / Time '-' Time.
```


Lecture Generating Software from Specifications WS 2013/14 / Slide 206

Objectives:

Classification of terminals

In the lecture:

Notation of terminals specified in different ways

Specification of Non-Literal Terminals

The generator GLA generates a scanner from

- notations of literal terminals, extracted from the concrete syntax by Eli
- specifications of non-literal terminals in files of type **.gla**

Form of specifications:

```
Name:      $  regular expression              [Coding function]
Day:       $  Mon|Tue|Wed|Thu|Fri|Sat|Son     [mkDay]
Time:      $(([0-9]|1[0-9]|2[0-3]):[0-5][0-9]) [mkTime]
```

Canned specifications:

```
Description:  C_STRING_LIT
Integer:      PASCAL_INTEGER
```


Lecture Generating Software from Specifications WS 2013/14 / Slide 207

Objectives:

Understand scanner specifications

In the lecture:

Explain

- Notation of regular expressions,
- Task and interface of coding function,
- canned specifications.

Scanner Specification: Regular Expressions

<table>
<tr><th>Notation</th><th>accepted character sequences</th></tr>
<tr><td>c</td><td>the character c; except characters that have special meaning, see \c</td></tr>
<tr><td>\c</td><td>space, tab, newline, \".[]^()|?+*{}/$<</td></tr>
<tr><td>"s"</td><td>the character sequence s</td></tr>
<tr><td>.</td><td>any single character except newline</td></tr>
<tr><td>[xyz]</td><td>exactly one character of the set {x, y, z}</td></tr>
<tr><td>[^xyz]</td><td>exactly one character that is not in the set {x, y, z}</td></tr>
<tr><td>[c-d]</td><td>exactly one character, the ASCII code of which lies between c and d (incl.)</td></tr>
<tr><td>(e)</td><td>character sequence as specified by e</td></tr>
<tr><td>ef</td><td>character sequences as specified by e followed by f</td></tr>
<tr><td>e | f</td><td>character sequence as specified by e or by f</td></tr>
<tr><td>e?</td><td>character sequence as specified by e or empty sequence</td></tr>
<tr><td>e+</td><td>one or more character sequences as specified by e</td></tr>
<tr><td>e*</td><td>character sequence as specified by e+ or empty</td></tr>
<tr><td>e {m,n}</td><td>at least m, and at most n character sequences as specified by e</td></tr>
</table>

e and f are regular expressions as defined here.

Each regular expression **accepts the longest character sequence**, that obeys its definition.

Solving ambiguities:

1. the **longer accepted sequence**
2. equal length: the **earlier stated rule**

Lecture Generating Software from Specifications WS 2013/14 / Slide 208

Objectives:

Notation of regular expressions

In the lecture:

Explain how to apply the definintions

Scanner Specification: Programmed Scanner

There are situations where the to be accepted character sequences are very difficult to define by a regular expression. A function may be implemented to accept such sequences.

The begin of the squence is specified by a regular expression, followed by the name of the function, that will accept the remainder. For example, line comments of Ada:

```
$-- (auxEOL)
```

Parameters of the function: a pointer to the first character of the so far accepted sequence, and its length.
Function result: a pointer to the charater immediately following the complete sequence:

```
char *Name(char *start, int length)
```

Some of the available programmed scanners:

auxEOL	all characters up to and including the next newline
auxCString	a C string literal after the opening "
auxM3Comment	a Modula 3 comment after the opening (*, up to and including the closing *); may contain nested comments paranthesized by (* and *)
Ctext	C compound statements after the opening {, up to the closing }; may contain nested statements parenthesized by { and }

Lecture Generating Software from Specifications WS 2013/14 / Slide 209

Objectives:

Recognize useful applications

In the lecture:

- Explain the principle and examples,
- refer to the list of available functions in the documentation.

Scanner Specification: Coding Functions

The **accepted character sequence** (`start`, `length`) is passed to a coding function.

It computes the code of the accepted token (`intrinsic`)
i.e. an **integral number, representing the identity of the token.**

For that purpose the function may **store and/or convert** the character sequence, if necessary.

All coding functions have the same **signature**:

```
void Name (char *start, int length, int *class, int *intrinsic)
```

The **token class** (terminal code, parameter `class`) may be changed by the function call, if necessary, e.g. to distinguish keywords from identifiers.

Available coding functions:

`mkidn` enter character sequence into a hash table and encode it bijectively

`mkstr` store character sequence, return a new code

`c_mkstr` C string literal, converted into its value, stored, and given a new code

`mkint` convert a sequences of digits into an integral value and return it value

`c_mkint` convert a literal for an integral number in C and return its value

Objectives:

Recognize the principle and useful applications

In the lecture:

- Explain the interface and examples
- refer to the list of available functions in the documentation

Scanner Specification: Canned Specifications

Complete canned specifications (regular expression, a programmed scanner, and a coding function) can be instantiated by their **names**:

```
Identifier:  C_IDENTIFIER
```

For many tokens of several programming languages canned specifications are available (complete list of descriptions in the documentation):

C_IDENTIFIER, C_INTEGER, C_INT_DENOTATION, C_FLOAT,
C_STRING_LIT, C_CHAR_CONSTANT, C_COMMENT

PASCAL_IDENTIFIER, PASCAL_INTEGER, PASCAL_REAL,
PASCAL_STRING, PASCAL_COMMENT

MODULA2_INTEGER, MODULA2_CHARINT, MODULA2_LITERALDQ,
MODULA2_LITERALSQ, MODULA2_COMMENT

MODULA3_COMMENT, ADA_IDENTIFIER, ADA_COMMENT, AWK_COMMENT

SPACES, TAB, NEW_LINE
are only used, if some token begins with one of these characters, but, if these characters still separate tokens.

The used coding functions may be overridden.

Objectives:

Recognize the potential for reuse

In the lecture:

- Explain some of the specifications,
- refer to the documentation

Abstract Syntax

specifies the **structure trees** using a context-free grammar:

```
RULE pCalendar:     Calendar LISTOF Entry           END;
RULE pEntry:        Entry ::= Date Event            END;
RULE pDateNum:      Date ::= DayNum MonNum          END;
RULE pDatePattern:  Date ::= Pattern                END;
RULE pDateDays:     Date ::= DayNames               END;
RULE pDayNum:       DayNum ::= Integer              END;
RULE pMonth:        MonNum ::= Integer              END;
RULE pDayNames:     DayNames LISTOF DayName         END;
RULE pDay:          DayName ::= Day                 END;
RULE pWeekday:      Pattern ::= 'Weekday'           END;
RULE pWeekend:      Pattern ::= 'Weekend'           END;
RULE pModifier:     Pattern ::= Pattern Modifier    END;
RULE pPlus:         Modifier ::= '+' DayNames       END;
RULE pMinus:        Modifier ::= '-' DayNames       END;
RULE pTimedEvent:   Event ::= When Description      END;
RULE pUntimedEvent: Event ::= Description           END;
RULE pTime:         When ::= Time                   END;
RULE pTimeRange:    When ::= Time '-' Time          END;
```

Notation:

- Language ***Lido*** for computations in structure trees
- optionally named productions,
- no EBNF, except **`LISTOF`** (possibly empty sequence)

Objectives:

Learn the notation for abstract syntax

In the lecture:

- Design of productions,
- notation of productions

Example for a Structure Tree

- Production names are node types
- Values of terminals at leaves

Tree output produced by Eli's unparser generator

```
pEntry( pDateNum(pDayNum(1),pMonth(11)),
        pTimedEvent(pTime(1200),"Theater")),

pEntry( pDateDays(pDay(4)),pTimedEvent(pTime(855),"GSS lecture")),

pEntry( pDatePattern(pWeekday()),
        pTimedEvent(pTime(725),"Dinner in Palmengarten")),

pEntry( pDateDays(pDay(1),pDay(4)),pUntimedEvent("Dean's office")),

pEntry( pDateNum(pDayNum(31),pMonth(12)),
        pTimedEvent(pTime(1439),"Jahresende")),

pEntry( pDateNum(pDayNum(31),pMonth(12)),
        pTimedEvent(pTime(1439),"End of year"))
```


Objectives:

Read tree in notation of named parenthesis

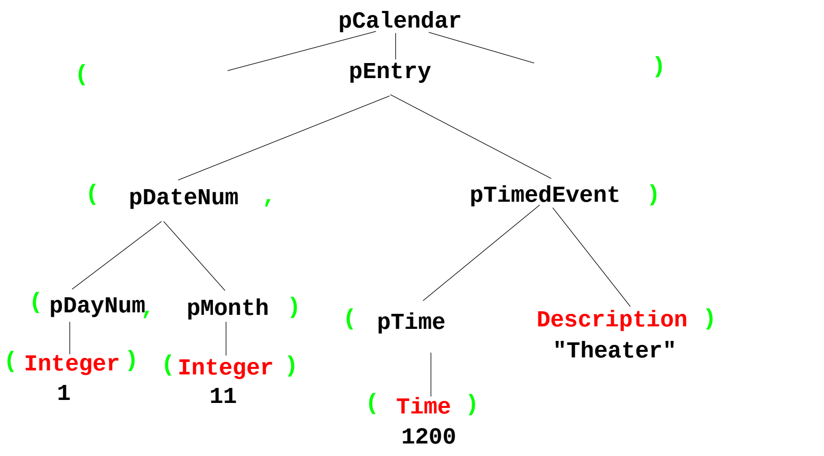
In the lecture:

- Relate to example input,
- relate to abstract syntax.

Graphic Structure Tree

- Names of productions as node types
- Values of terminals at leaves

Output produced by
Eli's unparser generator,
Tree structure given by parentheses



Lecture Generating Software from Specifications WS 2013/14 / Slide 214

Objectives:

Understand the tree representation

In the lecture:

Understand the relation between the abstract syntax (tree grammar) and the textual representation

Symbol Mapping: Concrete - Abstract Syntax

concrete syntax:

```
SimplePattern:  'Weekday' / 'Weekend'.

GeneralPattern: SimplePattern /
                SimplePattern Modifier.
```

simplify to create abstract syntax:

Set of nonterminals of the concrete syntax mapped to

one nonterminal of the abstract syntax

mapping:

```
MAPSYM
Pattern ::=  GeneralPattern
             SimplePattern.
```

abstract syntax:

```
RULE pWeekday:     Pattern ::= 'Weekday'                 END;
RULE pWeekend:     Pattern ::= 'Weekend'                 END;
RULE pModifier:    Pattern ::= Pattern Modifier          END;
```


Lecture Generating Software from Specifications WS 2013/14 / Slide 215

Objectives:

Simplification of the structure tree

In the lecture:

- Explain symbol mapping,
- cf. symbol mapping for expression grammars in (GPS-2-9)

Rule Mapping

Concrete Syntax:

```
Date:         DayNum '.' MonNum '.' /
              MonNum '/' DayNum .
```

Mapping:

```
MAPRULE
Date: DayNum '.' MonNum '.'  < $1 $2 >.
Date: MonNum '/' DayNum      < $2 $1 >.
```

Different productions of the concrete syntax

are **unified** in the abstract syntax

Abstract syntax:

```
RULE pDateNum:       Date ::= DayNum MonNum END;
```


Lecture Generating Software from Specifications WS 2013/14 / Slide 216

Objectives:

Tree simplification

In the lecture:

- Explain rule mapping,
- cf. simplification of expression grammars (GPS-2-9),
- abstract sytax can be genrated from concrete syntax and mapping specification,
- concrete syntax can be generated from abstract syntax and mapping specification,
- Abstract and concrete syntax can be matched, yielding the mapping specification.
- The grammars can be matched piecewise.

Generate Tree Output

Produce structure trees with node types and values at terminal leaves:

```
pEntry( pDateNum(pDayNum(1),pMonth(11)),
        pTimedEvent(pTime(1200),"Theater")),
```

Pattern constructor functions are called in tree contexts to produce output.

Specifications are **created automatically** by Eli's **unparser generator**:

Unparser is generated from the specification:

```
Calendar.fw
Calendar.fw:tree
```

Output at grammar root:

```
SYMBOL ROOTCLASS COMPUTE
   BP_Out(THIS.IdemPtg);
END;
```

Output of non-literal terminals:

```
Idem_Day:     $ int
Idem_Time:    $ int
Idem_Integer: $ int
```

Use predefined PTG patterns:

```
$/Output/PtgCommon.fw
```


Lecture Generating Software from Specifications WS 2013/14 / Slide 217

Objectives:

Learn to use the unparser generator

In the lecture:

Explain the roles of the specification

- Unparser generator generates Eli specifications (ptg and lido)!
- Individual specifications needed for the root and the leaves only.
- Another variant of the unparser generator can reproduce the input text: instead of ":tree" derive ":idem". It may be used for language extensions.