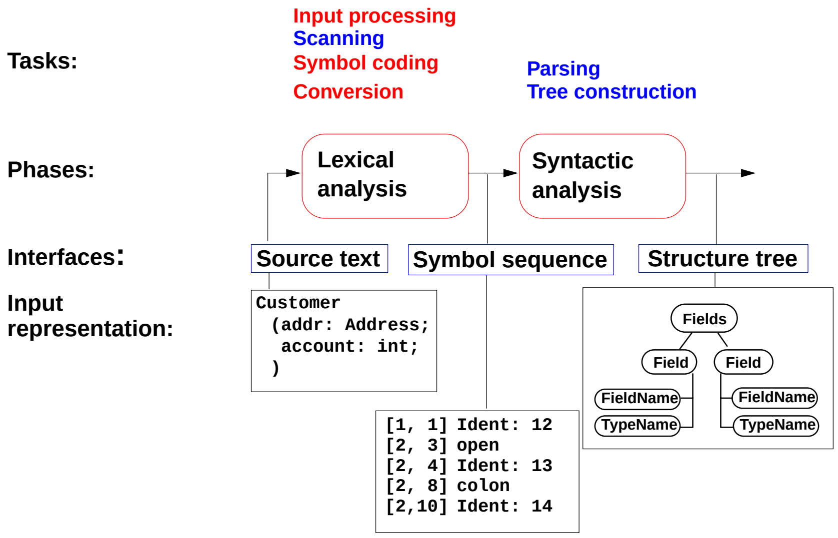
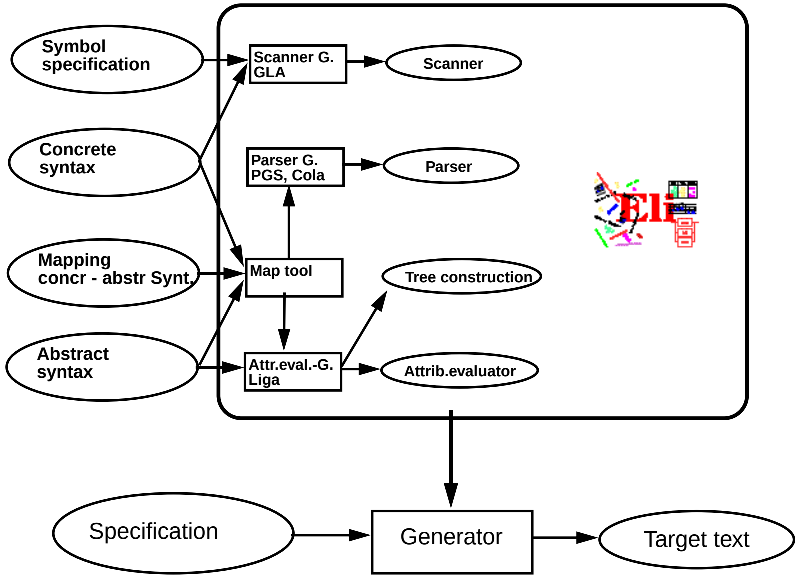
2. Constructing Trees - Overview

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



Eli: Specification of the Tree Construction



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

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

Abstract syntax

Structure of trees
.lido

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

Only those symbols and productions, which need computations

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"
```

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**.

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"
```


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.
```


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
```

Scanner Specification: Regular Expressions

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

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**

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 }

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

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.

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)

Example for a Structure Tree

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

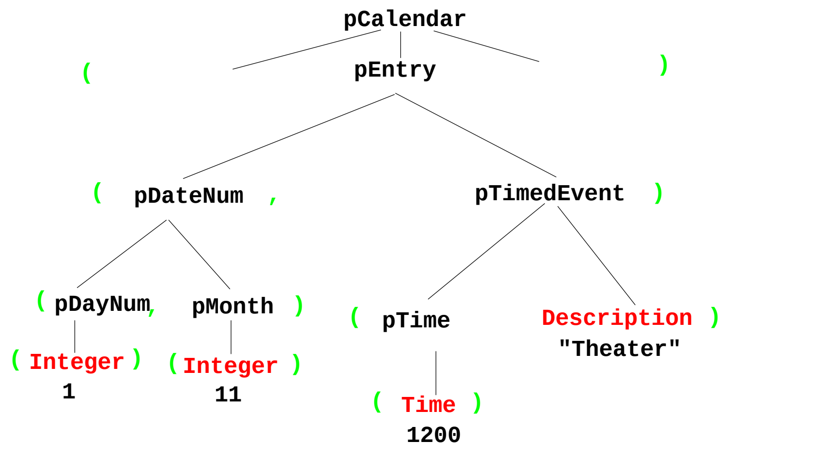
Tree output produced by Eli's unparser generator

```
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"))
```


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



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;
```

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;
```


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
```