4. Semantic Processing and Attributed Grammars

Semantic Processing

The parser checks only the *syntactic* correctness of a program

Tasks of semantic processing

- **Checking context conditions**
  - Declaration rules
  - Type checking

- **Symbol table handling**
  - Maintaining information about declared names
  - Maintaining information about types
  - Maintaining scopes

- **Invocation of code generation routines**

Semantic actions are integrated into the parser.
We describe them with *attributed grammars*

Semantic Actions

So far, we have just ***analyzed*** the input

```
Number = digit {digit}.
```

the parser checks if the input is syntactically correct (in this example *Number* is not viewed as part of the lexical structure of the language)

Now, we also ***translate*** it (semantic processing)

e.g.: we want to count the digits in the number

syntax	semantics
Number =	
digit	(. int n = 1; .)
{ digit	(. n++; .)
}	
	(. System.out.println(n); .)
.	

semantic actions

- arbitrary Java statements between **(.** and **.)**
- are executed by the parser at the position where they occur in the grammar

"translation" here:

123 ⇒ 3
4711 ⇒ 4
9 ⇒ 1

Attributes

Syntax symbols can return values (sort of output parameters)

```
digit <↑val>
```

digit returns its numeric value (0..9) as an output attribute

Attributes are useful in the translation process

e.g.: we want to compute the value of a number

```
Number                  (. int val, n; .)
= digit <↑val>
  { digit <↑n>          (. val = 10 * val + n; .)
  }
                        (. System.out.println(val); .)
  .
```

"translation" here:

"123" ⇒ 123

"4711" ⇒ 4711

"9" ⇒ 9

Input Attributes

Nonterminal symbols can have also input attributes
(parameters that are passed from the "calling" production)

```
Number <↓base, ↑val>
```

base: number base (e.g. 10 or 16)
val: returned value of the number

Example

```
Number <↓base, ↑val>    (. int base, val, n; .)
=  digit <↑val>
   { digit <↑n>         (. val = base * val + n; .)
   }.
```

Attributed Grammars

Notation for describing translation processes

consist of three parts

1. **Productions in EBNF**

```
IdentList = ident {"," ident}.
```

2. **Attributes** (parameters of syntax symbols)

ident<↑name>	output attributes (*synthesized*):	yield the translation result
IdentList<↓type>	input attributes (*inherited*):	provide context from the caller

3. **Semantic actions**

```
(.   ... arbitrary Java statements ...   .)
```

Example

ATG for processing declarations

```
VarDecl                       (. Struct type; .)
=  Type <↑type>
   IdentList <↓type>
   ";" .
```

```
IdentList <↓type>             (. Struct type; String name; .)
=  ident <↑name>              (. Tab.insert(name, type); .)
   { "," ident <↑name>        (. Tab.insert(name, type); .)
   } .
```

This is translated to parsing methods as follows

```
private static void VarDecl() {
   Struct type;
   type = Type();
   IdentList(type);
   check(semicolon);
}
```

```
private static void IdentList(Struct type) {
   String name;
   check(ident); name = t.val;
   Tab.insert(name, type);
   while (sym == comma) {
      scan();
      check(ident); name = t.val;
      Tab.insert(name, type);
   }
}
```

ATGs are shorter and more readable than parsing methods

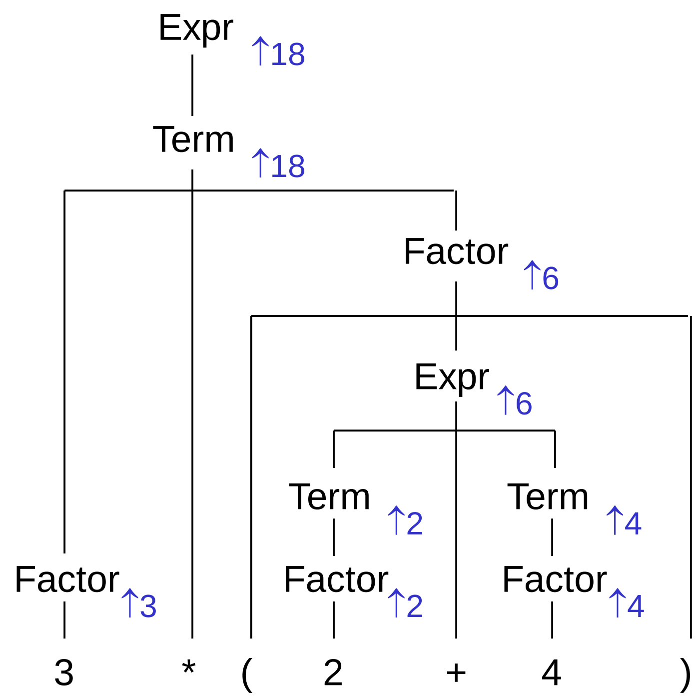
Example: *Processing of Constant Expressions*

input: 3 * (2 + 4)
desired result: 18

```
Expr<↑val>                      (. int val, val1; .)
= Term <↑val>
   { "+" Term <↑val1>           (. val = val + val1; .)
   | "-" Term <↑val1>           (. val = val - val1; .)
   }.

Term <↑val>                     (. int val, val1; .)
= Factor <↑val>
   { "*" Factor <↑val1>         (. val = val * val1; .)
   | "/" Factor <↑val1>         (. val = val / val1; .)
   }

Factor <↑val>                   (. int val, val1; .)
= number                        (. val = t.numVal; .)
|  "(" Expr<↑val>  ")"
```



Transforming an ATG into a Parser

Production

```
Expr <↑val>              (. int val, val1; .)
=  Term <↑val>
   { "+" Term <↑val1>    (. val = val + val1; .)
   | "-" Term <↑val1>    (. val = val - val1; .)
   }.
```

Parsing method

```
private static int Expr() {
   int val, val1;
   val = Term();
   for (;;) {
      if (sym == plus) {
         scan();
         val1 = Term();
         val = val + val1;
      } else if (sym == minus) {
         scan();
         val1 = Term();
         val = val - val1;
      } else break;
   }
   return val;
}
```

input attributes	⇒	parameters
output atribute	⇒	function value (if there are multiple output attributes encapsulate them in an object)
semantic actions	⇒	embedded Java code

Terminal symbols have no input attributes.

In our form of ATGs they also have no output attributes,

but their value can be obtained from *t.val* or *t.numVal*.

Example: Sales Statistics

ATGs can also be used in areas other than compiler construction

Example: given a file with sales numbers

```
File    = {Article}.
Article = Code {Amount} ";".
Code    = number.
Amount  = number.
```

Whenever the input is syntacticlly structured
ATGs are a good notation to describe its processing

Input for example:

```
3451    2  5  3  7  ;
3452    4  8  1 ;
3453    1  1 ;
...
```

Desired output:

```
3451    17
3452    13
3453    2
...
```

ATG for the Sales Statistics

```
File                                  (. int code, amount; .)
= { Article <↑code, ↑amount>          (. print(code + " " + amount); .)
  }.

Article <↑code, ↑amount>              (. int code, x, amount = 0; .)
= Number <↑code>
  { Number <↑x>                       (. amount += x; .)
  }
  ";".

Number <↑x>                           (. int x; .)
  = number                            (. x = t.numVal; .)
  .
```

Parser code

```
private static void File() {
    while (sym == number) {
        ArtInfo a = Article();
        print(a.code + " " + a.amount);
    }
}
```

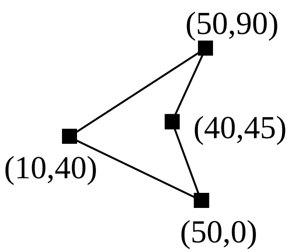
```
class ArtInfo {
    int code, amount;
}
```

```
private static ArtInfo Article() {
    ArtInfo a = new ArtInfo();
    a.amount = 0;
    a.code = Number();
    while (sym == number) {
        int x = Number();
        a.amount += x;
    }
    check(semicolon); return a;
}
```

```
private static int Number() {
    check(number);
    return t.numVal;
}
```

terminal symbols
- number
- semicolon
- eof

Example: Image Description Language



described by:

```
POLY
   (10,40)
   (50,90)
   (40,45)
   (50,0)
END
```

input syntax:

```
Polygon = "POLY" Point {Point} "END".
Point = "(" number "," number ")".
```

We want a program that reads the input and draws the polygon

```
Polygon                  (. Pt p, q; .)
= "POLY"
   Point<↑p>             (. Turtle.start(p); .)
   { Point<↑q>           (. Turtle.move(q); .)
   }
   "END"                 (. Turtle.move(p); .)
   .

Point<↑p>                (. Pt p; int x, y; .)
= "(" number             (. x = t.numVal; .)
   "," number            (. y = t.numVal; .)
   ")"                   (. p = new Pt(x, y); .)
   .
```

We use "Turtle Graphics" for drawing

Turtle.start(p);	sets the turtle (pen) to point *p*
Turtle.move(q);	moves the turtle to *q* drawing a line

```
class Pt {
   int x;
   int y;
   Pt (int x, int y) { this.x = x; this.y = y; }
}
```

Example: *Transform Infix to Postfix Expressions*

Arithmetic expressions in infix notation are to be transformed to postfix notation

3 + 4 * 2 ⇒ 3 4 2 * +
(3 + 4) * 2 ⇒ 3 4 + 2 *

```
Expr
= Term
   { "+" Term    (. print("+"); .)
   | "-" Term    (. print("-"); .)
   }.

Term
= Factor
   { "*" Factor  (. print("*"); .)
   | "/" Factor  (. print("/"); .)
   }.

Factor
= number         (. print(t.numVal); .)
| "(" Expr ")".
```