INF5110: Mandatory Exercise 1

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Slides are partly based on material from previous years, made by Henning Berg, Fredrik Sørensen, and others.

Main goal

Determine if programs written in the language Compila17 are *syntactically* valid.

- Write a scanner
- And a parser
- That is, the first parts of your own compiler!
- Compila17 is described in detail in a separate document available on the course page.

Learning outcomes

- Using tools for scanner and parser generation
  - JFlex and CUP
- Variants of a grammar for the same language
  - Transforming from one form (extended BNF) to another (grammars compatible with tools we will be using).
  - Controlling precedence and associativity
- Defining ASTs as node classes in Java
  - Using the parsing tools to build such trees
  - Pretty-printing ASTs.

The Compila17 language at a glance

```
program MyProgram
begin

 class Complex begin
   var Real : float;
   var Imag : float;
 end ;


 proc Add (a : Complex, b : Complex) : Complex
 begin
   var retval : Complex;
   retval := new Complex;
   retval.Real := a.Real + b.Real;
   retval.Imag := a.Imag + b.Imag;

   return retval;
end ;

 proc Main()
 begin
  var c1 : Complex;
  var c2 : Complex;
  var result : Complex;
  …
  result := Add ( c1, c2 );
  …
  return;
 end ;

end ;
```

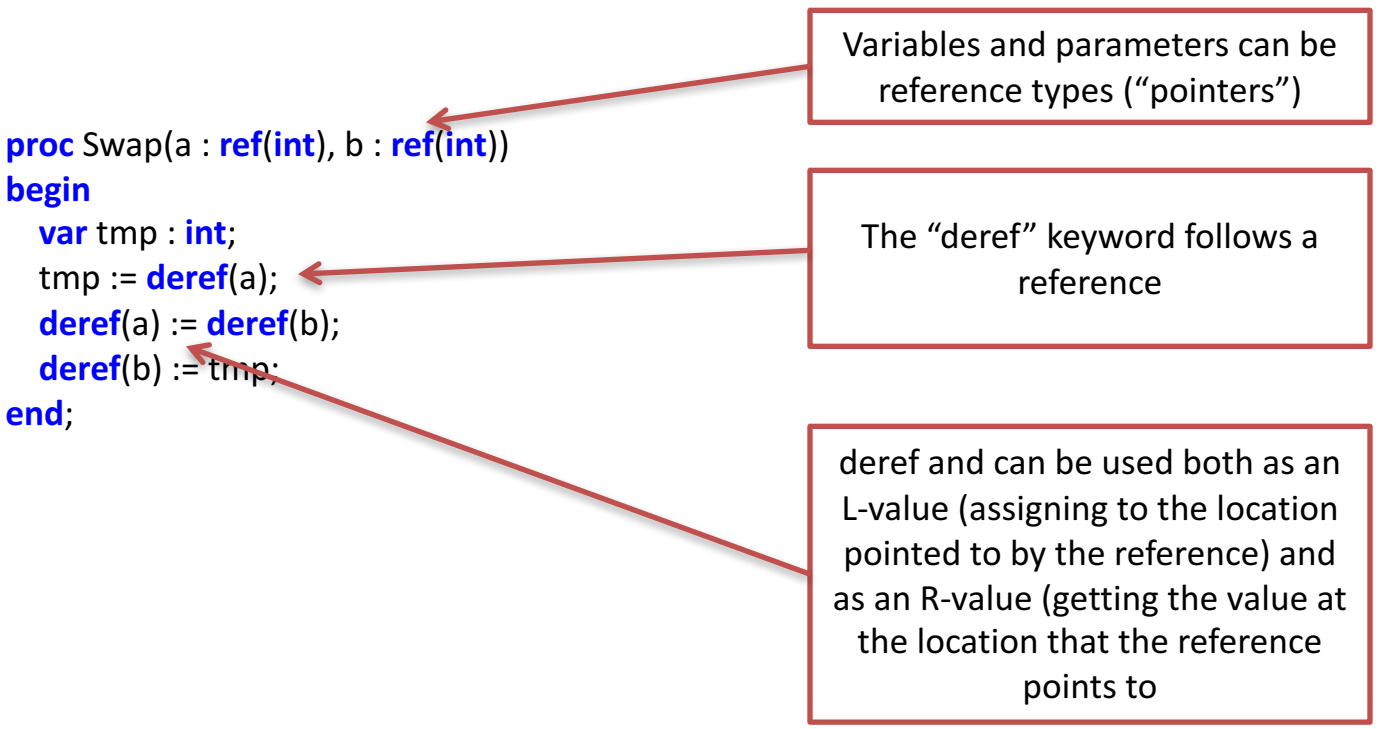
Programs are written enclosed in program NAME begin … end

The language supports very simple “classes”, but no real OO (inheritance, polymorphism, etc)

Procedures are declared within programs (but not within classes). They perform calculations and create new objects.

Execution starts in the Main method.

The Compila17 language at a glance (2)



Compila17 grammar

"terminal"
NON-TERMINAL
[optional]
{ repetition }
Alternative1 | Alternative2

```
PROGRAM         -> "program" NAME "begin" { DECL ";" }  "end" ";"

DECL            -> VAR_DECL | PROC_DECL | CLASS_DECL

VAR_DECL        -> "var" NAME ":" TYPE

PROC_DECL       -> "proc" NAME "(" [ PARAM_DECL { "," PARAM_DECL } ] ")"
                   [ ":" TYPE ] "begin" { DECL ";" } { STMT ";" } "end"

CLASS_DECL      -> "class" NAME "begin" { VAR_DECL ";" } "end"

PARAM_DECL      -> NAME ":" TYPE

EXP             -> EXP LOG_OP EXP | "not" EXP | EXP REL_OP EXP | EXP ARIT_OP EXP | "(" EXP ")"
                 | LITERAL | CALL_STMT | "new" NAME | VAR | REF_VAR | DEREF_VAR

REF_VAR         -> "ref" "(" VAR ")"
DEREF_VAR       -> "deref" "(" VAR ")" | "deref" "(" DEREF_VAR ")"

VAR             -> NAME | EXP "." NAME

LOG_OP          -> "&&" | "||"
REL_OP          -> "<" | "<=" | ">" | ">=" | "=" | "<>"
ARIT_OP         -> "+" | "-" | "*" | "/" | "#"

LITERAL         -> FLOAT_LITERAL | INT_LITERAL | STRING_LITERAL
                 | "true" | "false" | "null"

STMT            -> ASSIGN_STMT | IF_STMT | WHILE_STMT | RETURN_STMT | CALL_STMT
ASSIGN_STMT     -> VAR ":=" EXP | DEREF_VAR ":=" EXP

IF_STMT         -> "if" EXP "then" "begin" { STMT ";" } "end"
                   [ "else" "begin" { STMT ";" } "end" ]
WHILE_STMT      -> "while" EXP "do" "begin" { STMT ";" } "end"

RETURN_STMT     -> "return" [ EXP ]

CALL_STMT       -> NAME "(" [ EXP { "," EXP } ] ")"

TYPE            -> "float" | "int" | "string" | "bool" | NAME
                 | "ref" "(" TYPE ")"
```

Tool: JFlex

- A tool to easily (YMMV) generate *scanners*
  - Input: lexical specification
  - Output: scanner program written in Java

- The lexical specification is written in a .lex file
  - Consists of three separate parts
    - User code
    - Options and macros
    - Lexical rules

oblig1.lex

User code

```
package oblig1parser;
import java_cup.runtime.*;
```

Copied to the generated class, before the class definition

```
%%
```

Options/ macros

```
%class Lexer
%unicode
%cup
```

Options (class name, unicode support, CUP integration)

Defined in package java_cup.runtime.

```
%{
  private Symbol symbol(int type) {
    return new Symbol(type, yyline, yycolumn);
  }

%}
LineTerminator = \r|\n|\r\n
```

Inserted into generated class

Variables holding current line/column

Macros, defined as regular expressions

```
%%
```

Lexical rules

```
<YYINITIAL>
{
    "program"       { return symbol(sym.PROGRAM); }
    "class"         { return symbol(sym.CLASS); }
    “begin”         { return symbol(sym.BEGIN); }
    “end”           { return symbol(sym.END); }
    “var”           { return symbol(sym.VAR); }
     …
}
```

The following rules are applicable from the initial state

Refers to names in the .cup file (next slides)

Lexical rules

Tool: CUP – *Construction of Useful Parsers* - for Java

- A tool to easily (YMMV) generate *parsers*
  - Reads tokens from the scanner using **next_token**()
    - The **%cup** option (prev. slide) makes this work
  - Input: Grammar defined as BNF with *action code*

Assign names to parts of production so we can reuse them in action code

```
var_decl  ::= VAR ID:name COLON type:vtype
 {: RESULT = new VarDecl(name, vtype); :};
```

Build AST with user defined node classes (java code)

  - Output: a parser program written in Java

Package/ imports

```
package oblig1parser;
import java_cup.runtime.*;
import syntaxtree.*;
```

Package name for generated code and imports of packages we need

The syntaxtree package contains our own AST classes

User code

```
parser code {: :};
```

Code between {: and :} is inserted directly into the generated class (parser.java)

Symbol list

```
terminal            PROGRAM, CLASS;
terminal            BEGIN, END;
…
terminal            String      ID;
terminal            String      STRING_LITERAL;

non terminal        Program           program;
non terminal        List<ClassDecl>   decl_list;
non terminal        ClassDecl         class_decl, decl;
```

Terminals and non-terminals are defined here. They can also be given a Java type for the "value" that they carry, e.g. a node in the AST

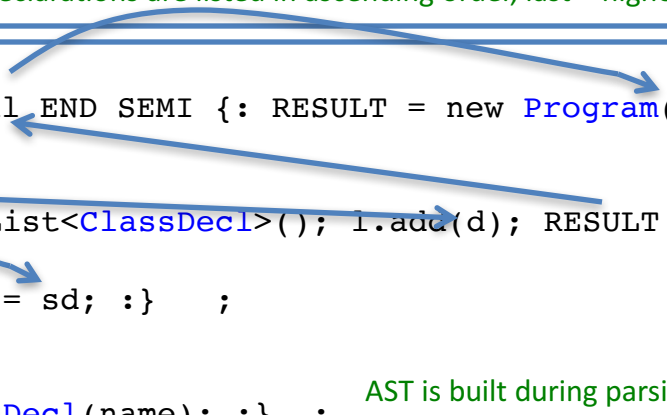
Precedence

```
precedence left     AND;
```

Precedence declarations are listed in ascending order, last = highest

Grammar

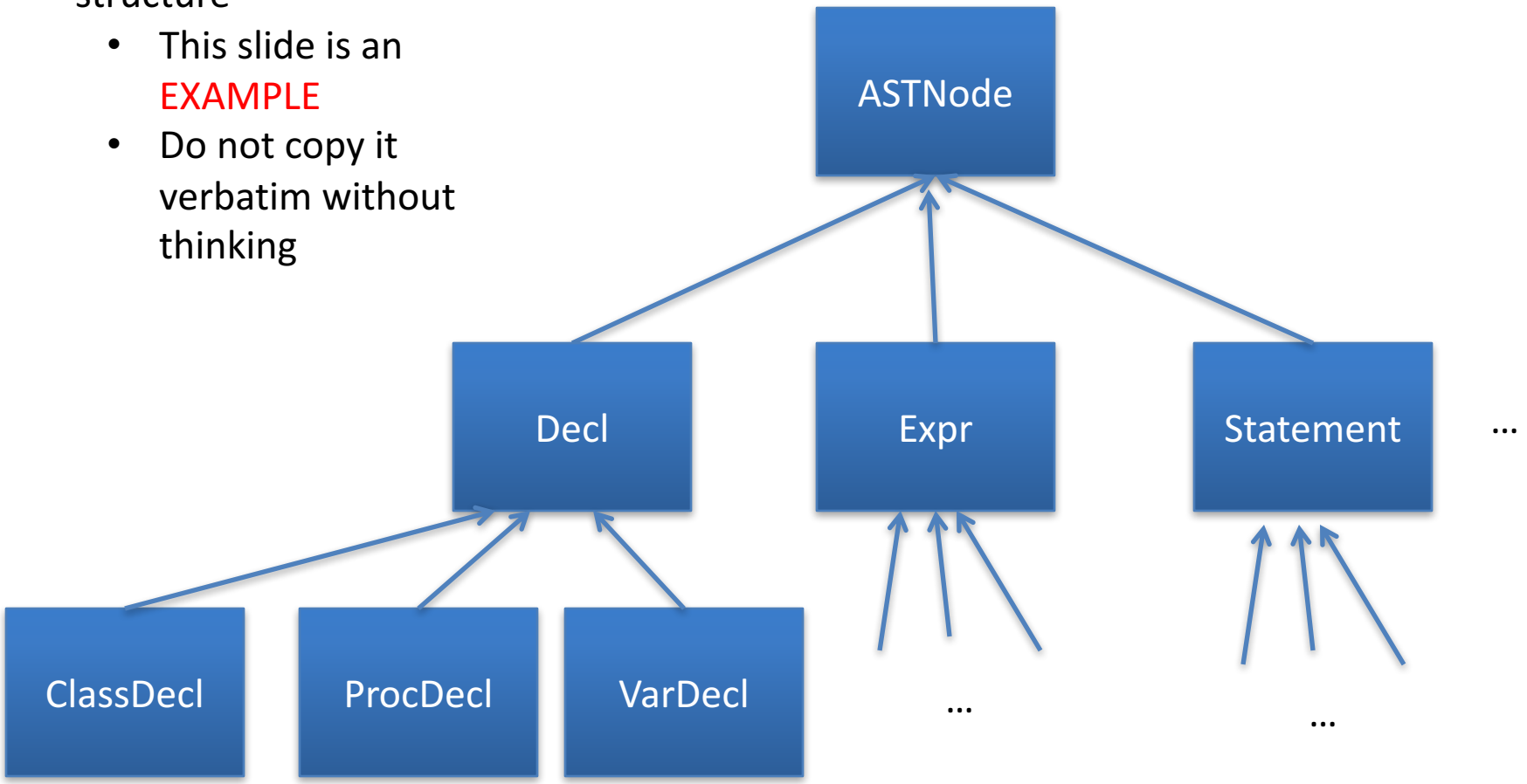
```
program     := PROGRAM BEGIN decl_list:dl END SEMI {: RESULT = new Program(dl); :} ;

decl_list   ::= decl:d
      {: List<ClassDecl> l = new LinkedList<ClassDecl>(); l.add(d); RESULT = l; :} ;

decl        ::= class_decl:sd {: RESULT = sd; :}   ;

class_decl  ::= CLASS ID:name BEGIN END
                    {: RESULT = new ClassDecl(name); :}  ;
```



AST is built during parsing. The left hand side of each production is implicitly labeled RESULT.

AST classes

- Make a reasonable structure
  - This slide is an EXAMPLE
  - Do not copy it verbatim without thinking



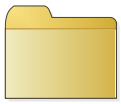
Tool:

- A Java-based build tool
  - Configuration in build.xml
    - Can contain different targets, for instance test, clean, build, run, etc
  - The supplied configuration takes care of calling jflex, cup and javac for you.
    - Note that ant might continue even if jflex or cup encounter errors!

Provided source code

build

Class files for compiler, lexer, parser, syntaxtree, etc.



compila-code

Compila source code

[compila.cmp](#)
Compila source file; this is the file you need to parse in this exercise

[expression-eval.cup/lex](#)
Example expression language
[expression-par.cup/lex](#)
Example language that handles parentheses
[oblig1.cup/lex](#)
Starting point for your grammars in this exercise

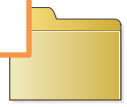
ammars

Three pairs of .lex/.cup files

src

Java source code for compiler, syntax tree, etc.

[ClassDecl.java,](#)
Starting point for AST node implementations in Java
[Compiler.java](#)
The main entry point for the compiler. You do not necessarily have to change this



input-examples

Test file for example parser

src-examples

Java source code example syntax tree

lib

JFlex and CUP libs

src-gen

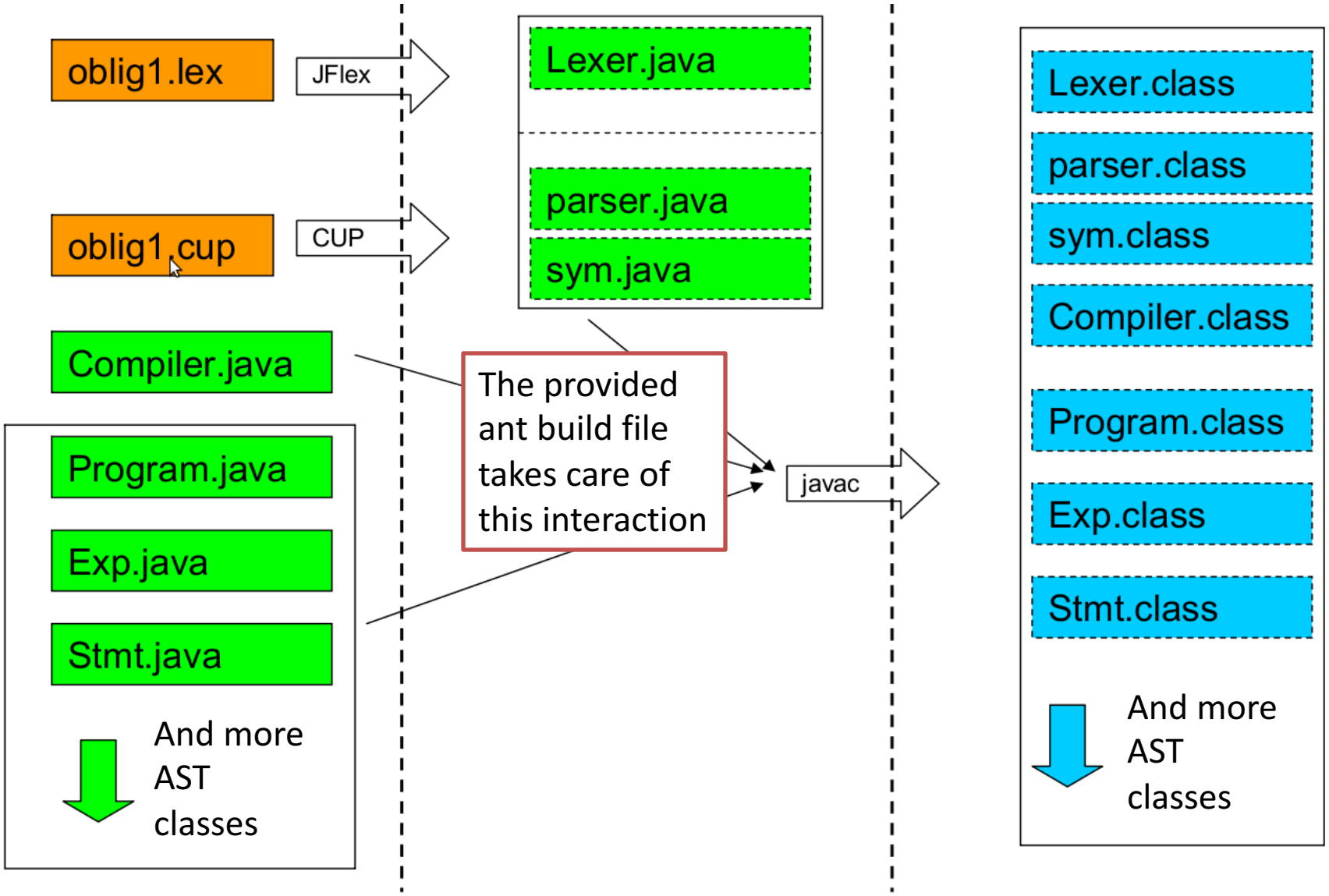
Generated Java source code for lexer and parser

mpila-ast

Generated abstract syntax tree

[compila.ast](#)
Example showing how your pretty-printed AST could (should) look

Putting it all together



DEADLINE

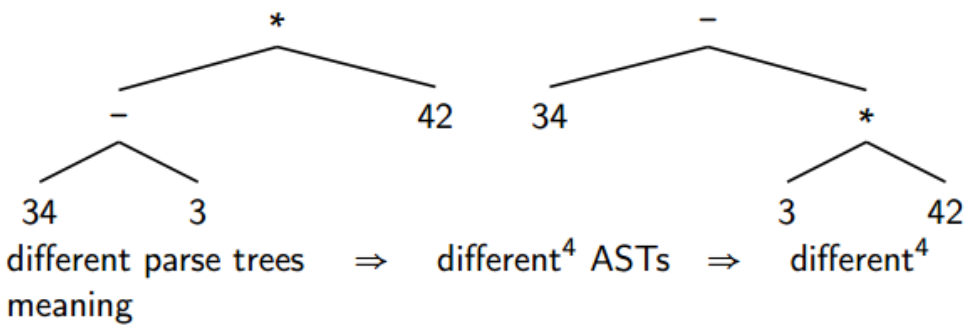
- March 19th, 2017 @ 23:59
- Don’t miss the deadline!
  - Extensions are only possible if you have an agreement with the student administration (studadm)
  - Contact them if you are sick, etc.
- Even if you are not 100% finished, deliver what you have before the deadline

Deliverables

- Working parser for Compila17
  - Parse the supplied example program
    - Must parse the class and at least 3 out of 4 procedures correctly
  - Printout of the resulting AST in textual form, example in the code you are given

- Two grammars (two .cup-files)
  - One ambiguous, with ambiguities resolved through precedence declarations in CUP
    - E.g. `precedence left AND;`
  - One inherently unambiguous grammar:

From Martin's slides: 34 - 3 * 42



$$
\begin{array}{rcl}
\mathit{exp} & \rightarrow & \mathit{exp}\ \mathit{addop}\ \mathit{term} \mid \mathit{term} \\
\mathit{addop} & \rightarrow & + \mid - \\
\mathit{term} & \rightarrow & \mathit{term}\ \mathit{mulop}\ \mathit{factor} \mid \mathit{factor} \\
\mathit{mulop} & \rightarrow & * \\
\mathit{factor} & \rightarrow & (\ \mathit{exp}\ ) \mid \textbf{number}
\end{array}
$$

Deliverables

- Report
  - Front page with your name(s) and UiO user name(s)
    - We **strongly** encourage you to work in pairs
    - Groups of three can be allowed after an application
  - Discussion of your solution
  - A comparison of the two grammars
- The code you supply must build with “ant”
  - Test your delivery on a UiO computer
- Deliver a zipped folder via Devilry (devilry.ifi.uio.no)
  - Tell me who you work with, so that I can create groups in Devilry for your delivery
  - Feel free to send questions at any time!
  - Read the exercise description thoroughly!