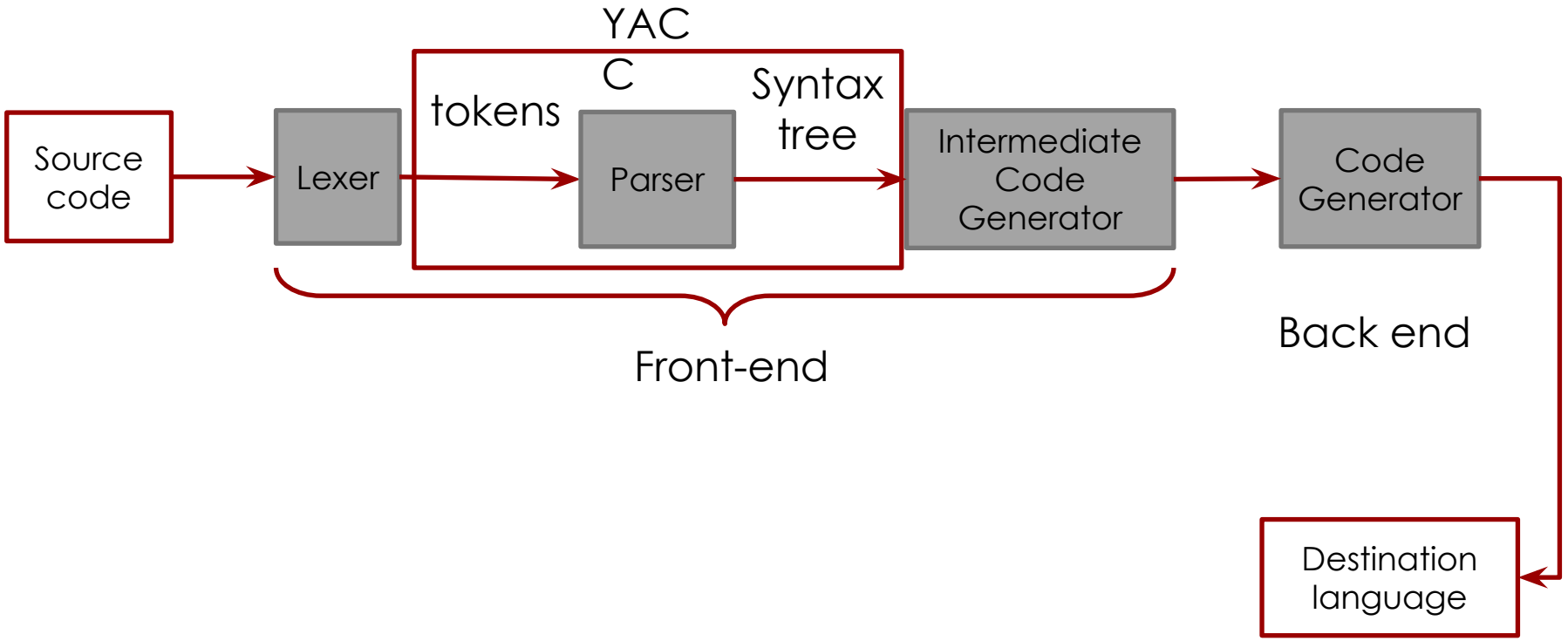
Formal Languages and Compilers

YACC

What is yacc?

- Yacc = **Y**et **A**nother **C**ompiler **C**ompiler
- Describing how the input of the source file must be, in other words define what kind of structure a program or a portion of it must have
- Describe what to do when such input is recognised
- So is a tool for describing specifications
  Concretely we will use it to describe our grammar
  (LALR + disambiguation rules)
- Nowadays substituted by a more powerful tool called bison

Front-end structure



YACC

- Yacc calls a function to obtain the input
  (a lexical analyser)
  Lexer recognises the *terminal symbols = token*
- Control the input process
- Organise tokens wrt the given structure.
  The parser recognises a structure(part or an entire production) which corresponds to a series of terminal and non terminal symbols
- To each grammar production can be bound an action

Basic structure of yacc source file

- Similar to Lex, 3 sections: declarations – grammar + actions – program/user routine

  Declarations
  %%
  rules
  %%
  programs

- As well as lex we can have empty sections but not the rules one

  %% declaration is empty
  rules program is empty

Basic input

- Take the basic file (basic.y)
- This is a senseless grammar invented for approaching purposes.
- Compile it with yacc basic.y
- What did happen?

Basic input (cont.)

- Yacc is enough user-friendly
- It tells us if the grammar is ambiguous
- Tells us if we have unused production
- Helps us in spotting grammar conflicts..
- We will see some complex examples in which it will prompt very useful messages, concerning the usage of the rules and the actions.
- Try with basic1.y and basic2.y

The source file: Rules section

- One or more grammar rule
  A: Body1;
  A: Body2;
  A: Body3;

  they can be grouped in
  A: Body1 |Body2 |Body3
- Case sensitive
- All C escapes recognized eg: \n, \r, \f, octal numbers, so on..
- Starting symbol specified with the use of %start…
  or by default is the first found!
- Let's have an example (firstgrammar
- .y)

Rules section - Actions

- An action is an arbitrary C statement that can be bound to one or more grammar rule.

EG:

```
A : ( expr )        {printf("helloooo");}
```

- Return/push or obtain values
- Actions are not executed right immediately, they are based and make use of a stack. Must reduce the recognized rule before
- "$" is used to signal to Yacc the stack position (in the stack)

Rules section – Actions cont.

The lexical analyser..

- Is a function called ***yylex***
- Such function returns a token number corresponding to the token read
- If the token has a value associated it should be associated with a value called ***yylval***
- Does such functions recall you something…?

The lexical analyser..

- Is a function called ***yylex***
- Such function returns a token number corresponding to the token read
- If the token has a value associated it should be associated with a value called ***yylval***
- Lex is designed to work in harmony with Yacc
- Btw Lex is not compulsory – but is really useful

The parser produced

- The parser is just another C program
- The parser is a finite state machine
- It uses a stack
- Can read another input token (***lookahead*** token)
- 4 action possible for such machine
  SHIFT
  REDUCE
  ACCEPT
  ERROR

The parser – parsing rules

- Parsing is done following some intuitive rules.. That are?

The parser – parsing rules

- Parsing is done by following two easy rules
- Look at current state
  if current state is not enough call yylex() and obtain the next token (lookahead)
- Use current state + lookahead
  decide next action and executes it.
  Action may push states on the stack or pop them off the stack.
  (Using a production will consume a certain number of tokens).
  Lookahead may be processed or left unconsumed for next interaction.

The parser – accept/error

- Accept → ALL the input was read, the structure of the input fits the specifications provided. The last token read must be the end marker (**$**).
- If we reach such a point the parser did correctly its job
- Error → some input was read but… the parser can not find a matching respecting the specification given.
- Token so far + lookahead token does not correspond to any legal input (eg. the action in the parsing table is empty)

The parser - shift

- The most common action that the parser undertakes.
- Is used mostly together with the lookahead token which, after the shift action, is cleared
- It tells the parser to move its current state to another

  EG lookahead for IF statements,
  Looks if the are any dangling ELSE or whatever

The parser - reduce

- Happens when right hand of a production is recognized
- Replace right hand side with left hand side
- Pop off states from the stack and push a new state on top of it
- Reduce actions manages also the value stack (the one that holds the $ values used in the actions)

The parser - description

- Yacc is really powerful and can produce a file which describe the parser for us (enough human readable of course)
- Helpful to manage and correct conflicts
  EG:
  reduce-reduce
  shift-reduce
- Can produce some statistic about the grammar
- Yacc –v file.y
  will produce y.output

Description example

- Let's proceed with an example

```
%token DING DONG DELL
%%
rhyme : sound place;
sound: DING DONG;
place: DELL;
```

- Yacc –v file.y –o yourname
  Open yourname.output and take a look...

Description example (cont)

- Let's look at the states 0 to 7
- _ or . Used to indicate what has been read so far (recall we are using item sets)
- Suppose input is DING DONG DELL
- Let's proceed in understanding what's the parser job
- The initial state is zero thus we start by looking at that one.

- Look at input in order to decide between actions in state 0
- (state 0) First token in: DING, is read – becoming the lookahead token
  in state 0 upon reading DING we have a shift and ***go to*** state 1
  State 1 is pushed into the stack, lookahead is cleared.
- (state 1) DONG is read becoming the lookahead.
  On token DONG in state 1 action is a shift, and a go to state 4.
  So state 4 is pushed onto the stack and lookahead is cleared.
- (state 4) on the stack we have states 0 1 4
  In state 4 we don't read any token, the default action is a reduce by rule 2 (which is written right above the $default)
  reduce by "sound : DING DONG"
  2 symbols on the right hand side thus 2 states popped of the stack → state 0 is now again on top
- (state 0) for *sound* we have a go to state 3
- (state 3) read DELL, which becomes the lookahead token.
  Action for DELL corresponds to a SHIFT and go to state 6, thus state 6 is pushed onto the stack.

- Recall last action of previous slide
  (state 3) read DELL, which becomes the lookahead token.
  Action for DELL corresponds to a SHIFT and go to state 6, thus state 6 is pushed onto the stack.

- (state 6) like we did for state 4. the default action is undertaken and we do a REDUCE action using rule 3
  reduce using "place : DELL"
  state 6 which is on top of the stack is popped off – due to only having 1 symbol on the right hand side of the production 3

- (state 3) again on state 3, we have for *place (the left hand side of production 3) the action* go to state 7
  the stack contains 0 3 and 7 now, which is the current state

- *(state 7) we reduce by using the rule number 1*
  reduce by "rhyme: sound place"
  we pop off 2 states from the stack (corresponding to the 2 symbols sound and place) state 0 is now uncovered

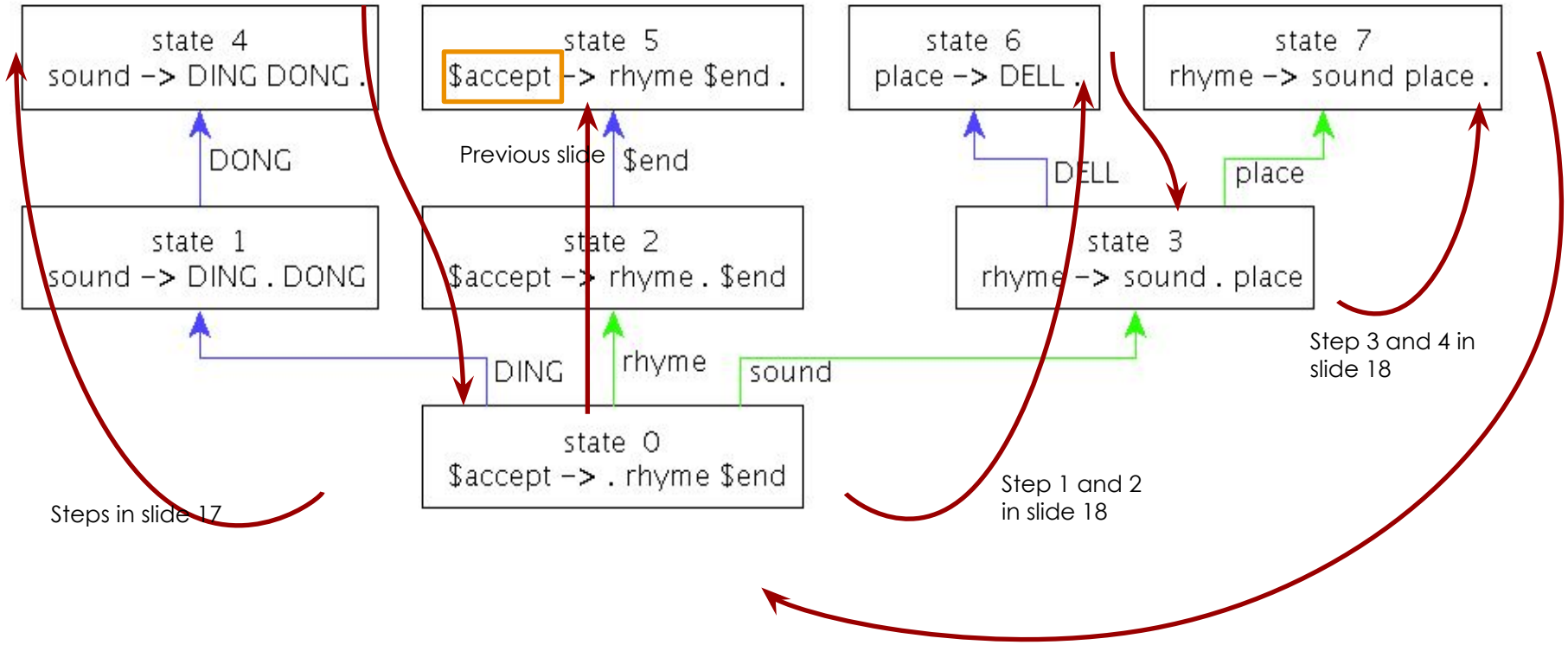
- *(state 0) in state 0, for the LH of production 1 we have a goto 2*

- Recall last action of the previous slide
  (state 0) in state 0, for the LH of production 1 we have a goto 2

- (state 2) – currently on the stack we have 0 and 2
  we read the next token, which in this case signals the end of the inpu → $end
  for such token we have a shift, such lookahead is cleared and we go to state 5 by pushing it onto the stack.

- (state 5) a default action which is the accept one.
  The parser has correctly done it's job.

Parser graph



exercises

Try to proceed as we did in previous slides with the following inputs:

DING DONG DONG

DING DONG

DING DONG DELL DELL

what does happen?

Ambiguous grammars

- What does mean that a grammar is ambiguous?
- Take expr : expr – expr (take – a as token)
  then
  expr – expr – expr
  means..?

Ambiguous grammars

- What does mean that a grammar is ambiguous?
- Take expr : expr – expr (take – a as token)
  then
  expr – expr – expr
  means..?
  (expr - expr) – expr left association
  or
  expr – (expr – expr) right association
- Yacc may find some difficulties in doing a choice when in such a situation

Ambiguous grammar

- Expr – expr – expr
- The parser reads "expr - expr"
  what to do now?
- **REDUCE**… "-expr" remains in the input → another reduce is done
- **DEFER** the application of the rule → read the input until
  expr – expr – expr
- Apply the rule to the rightmost symbols → obtain expr - ***expr1***
  (expr1 is obtained by previous reduction)
- Now 2 choises: shift or reduce → the parser doesn't know what to do..
  But it can be instructed!

Ambiguous grammar

- Ambiguous grammar is driver for 2 kind of problems related to parsers
- **REDUCE / REDUCE conflict**
  when the parser has a choice of two legal reduction, but doesn't know what to do
- **SHIFT / REDUCE conflict**
  as the previous example, the parser has a choice to shift or reduce, but doesn't know how to act

Disambiguating rules

- Yacc's disambiguating default rules:

  1) in a shift/reduce conflict → shift
  (normally but reduction may happen as well in certain cases)

  2)in a reduce/reduce conflict → reduce by the earlier grammar rule
  (following the input sequence of specifications)

```
Stat    :   IF '(' cond ')' stat
        |   IF '(' cond ')' stat ELSE stat
        ;
```

INPUT: "IF (C1) IF (C2) S1 ELSE S2"

POSSIBLE STRUCTURE given the previous rules:

```
IF (C1) {
   IF (C2) S1
}
ELSE S2
```

```
IF (C1) {
   IF (C2) S1
   ELSE S2
}
```

This is a clear shift/reduce conflict

The possible and desired grouping (the one on the right) is obtained by applying the disambiguating rule number 1 → shifting and binding the else to the previous if

Precedence of operators

- Resolving conflict is not always sufficient
- Arithmetic expression can not be resolved by removing the conflicts
- We need ***precedence*** of operators and information about left or right **associativity**

A note

- It turns out that
  "ambiguous grammar with appropriate disambiguating rules can create parsers that are faster and easier to write than those from unambiguous grammars"
- can anyone guess why?

Yacc – precedence

- Precedence management is attached to tokens (in the declaration section - obviously)

- %left '+' '-'
- %left '*' '/'
- Lines must be listed in order of increasing precedence (from bottom to top)

Yacc – precedence (cont)

- Take '–' in an arithmetical operation
  is meant as binary operator
  is meant as unary operator
  How to manage such situation?

- Use **%prec** in the rules, right after the body – followed by the token or before semicolon.
  EG:
  expr : ….
  | ….
  | '-' expr %prec '*'
  …

Disambiguating rules – part 2

- Associativity and precedence raise new disambiguating rules

1) **precedence** and **associativity** are recorded for those tokens and literals that have them declared

2) A prec. or association is bound with each rule: it is the prec or association of the last token or literal in the body.
If **%prec** is found it overrides the previous rule

3) If reduce/reduce or shift/reduce is found and no prec or association is declared → apply previous rules (see disambiguating rules slide)

4) If shift/reduce is found and both the grammar rule and the input char have precedence and associativity associated with them → conflict solved in favour of action with higher precedence.

Yacc environment

- Yacc turns specifications into a C program
- Yacc generates a function called ***yyparse()*** which calls repeatedly yylex
- Main must be defined if we want to manage some stuff (including calling yyparse) - like we did for lex.
- *yyerror* is called when an error is found, thus we can write this function as well to provide custom error management
- Yacc has a library with a default version of main and yyerror

Conclusion

- Yacc provides a parsing tool
- It needs as input a tokenized stream, which has to organized in a given - well defined - structure
- Lex provides a way to tokenize an input stream
- Next time we will put together lex and yacc

Exercises

- For next time try the following exercises
- Try to parse the following grammars with Yacc, decide which are the tokens and which the LH symbols. If you find conflicts try to fix them by using disambiguating rules
- S → AB;
  A → a | ε;
  B → bB | b;
- S → a | AbC;
  A → a;
  C → A | c;

Exercises

- Statement → IF '(' Boolexpr ')' Statement | IF '(' Boolexpr ')' Statement ELSE Statement | Expr ;

  Boolexpr: bool ;

  Expr : id ;

Exercises

- phrase → cart_animal AND CART
  | work_animal AND PLOW;

  cart_animal → HORSE | GOAT;
  work_animal → HORSE | OX;

- Is the grammar ambiguous? Is the grammar LALR? LR (0) or SLR?
- Think about a grammar for a simple calculator.

Bibliography

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- Lex and yacc tutorial by Tom Niemann
- Lex and yacc O'reilly
- http://docs.oracle.com/cd/E19620-01/805-4035/6j3r2rqn3/index.html