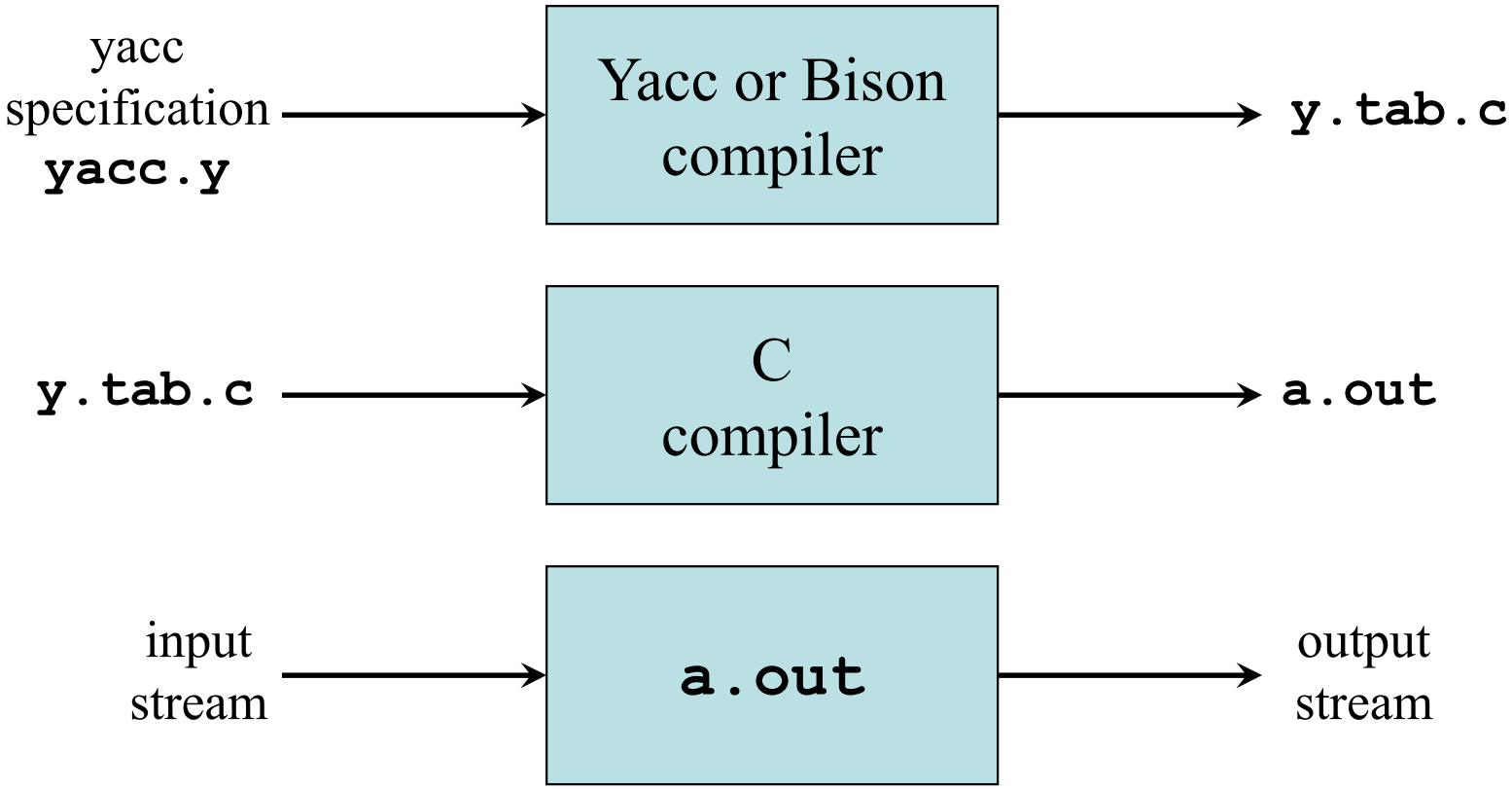
ANTLR, Yacc, and Bison

- *ANTLR* tool
  - Generates LL(*k*) parsers
- *Yacc* (Yet Another Compiler Compiler)
  - Generates LALR parsers
- *Bison*
  - Improved version of Yacc

Creating an LALR(1) Parser with Yacc/Bison



Yacc Specification

- A *yacc specification* consists of three parts:

  yacc declarations, and C declarations within `%{ %}`

  `%%`

  translation rules

  `%%`

  user-defined auxiliary procedures

- The *translation rules* are productions with actions:

  $production_1$ { $semantic\ action_1$ }
  $production_2$ { $semantic\ action_2$ }
  …
  $production_n$ { $semantic\ action_n$ }

Writing a Grammar in Yacc

- Productions in Yacc are of the form

  Nonterminal **:** tokens/nonterminals { *action* }
  | tokens/nonterminals { *action* }
  …
  ;

- Tokens that are single characters can be used directly within productions, e.g. **'+'**
- Named tokens must be declared first in the declaration part using

  %token *TokenName*

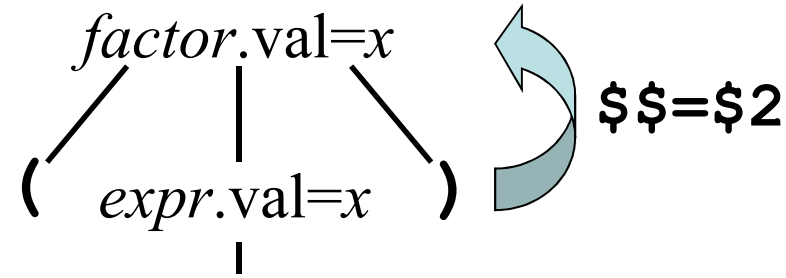
Synthesized Attributes

- Semantic actions may refer to values of the *synthesized attributes* of terminals and nonterminals in a production:

  $X : Y_1\ Y_2\ Y_3\ \ldots\ Y_n \quad \{\ action\ \}$

  - **`$$`** refers to the value of the attribute of X
  - **`$`***i* refers to the value of the attribute of Y_i
- For example

  `factor : '(' expr ')' { $$=$2; }`



Example 1

```
%{ #include <ctype.h> %}
%token DIGIT
%%
line    : expr '\n'             { printf("= %d\n", $1); }
        ;
expr    : expr '+' term         { $$ = $1 + $3; }
        | term                  { $$ = $1; }
        ;
term    : term '*' factor       { $$ = $1 * $3; }
        | factor                { $$ = $1; }
        ;
factor  : '(' expr ')'          { $$ = $2; }
        | DIGIT                 { $$ = $1; }
        ;
%%
int yylex()
{ int c = getchar();
  if (isdigit(c))
  { yylval = c-'0';
    return DIGIT;
  }
  return c;
}
```

Also results in definition of **`#define DIGIT xxx`**

Attribute of **`factor`** (child)

Attribute of **`term`** (parent)

Attribute of token (stored in **`yylval`**)

Example of a very crude lexical analyzer invoked by the parser

Dealing With Ambiguous Grammars

- By defining operator precedence levels and left/right associativity of the operators, we can specify ambiguous grammars in Yacc, such as $E \rightarrow E$**+**$E \mid E$**-**$E \mid E$*****$E \mid E$**/**$E \mid$ **(**E**)** $\mid$ **-**$E \mid$ **num**
- To define precedence levels and associativity in Yacc's declaration part:

```
%left '+' '-'
%left '*' '/'
%right UMINUS
```

Example 2

```
%{
#include <ctype.h>
#include <stdio.h>
#define YYSTYPE double
%}
%token NUMBER
%left '+' '-'
%left '*' '/'
%right UMINUS
%%
lines   : lines expr '\n'        { printf("= %g\n", $2); }
        | lines '\n'
        | /* empty */
        ;
expr    : expr '+' expr          { $$ = $1 + $3; }
        | expr '-' expr          { $$ = $1 - $3; }
        | expr '*' expr          { $$ = $1 * $3; }
        | expr '/' expr          { $$ = $1 / $3; }
        | '(' expr ')'           { $$ = $2; }
        | '-' expr %prec UMINUS  { $$ = -$2; }
        | NUMBER
        ;
%%
```

Double type for attributes and **`yylval`**

Example 2 (cont'd)

```
%%
int yylex()
{ int c;
  while ((c = getchar()) == ' ')
    ;
  if ((c == '.') || isdigit(c))
  { ungetc(c, stdin);
    scanf("%lf", &yylval);
    return NUMBER;
  }
  return c;
}
int main()
{ if (yyparse() != 0)
    fprintf(stderr, "Abnormal exit\n");
  return 0;
}
int yyerror(char *s)
{ fprintf(stderr, "Error: %s\n", s);
}
```

Crude lexical analyzer for fp doubles and arithmetic operators

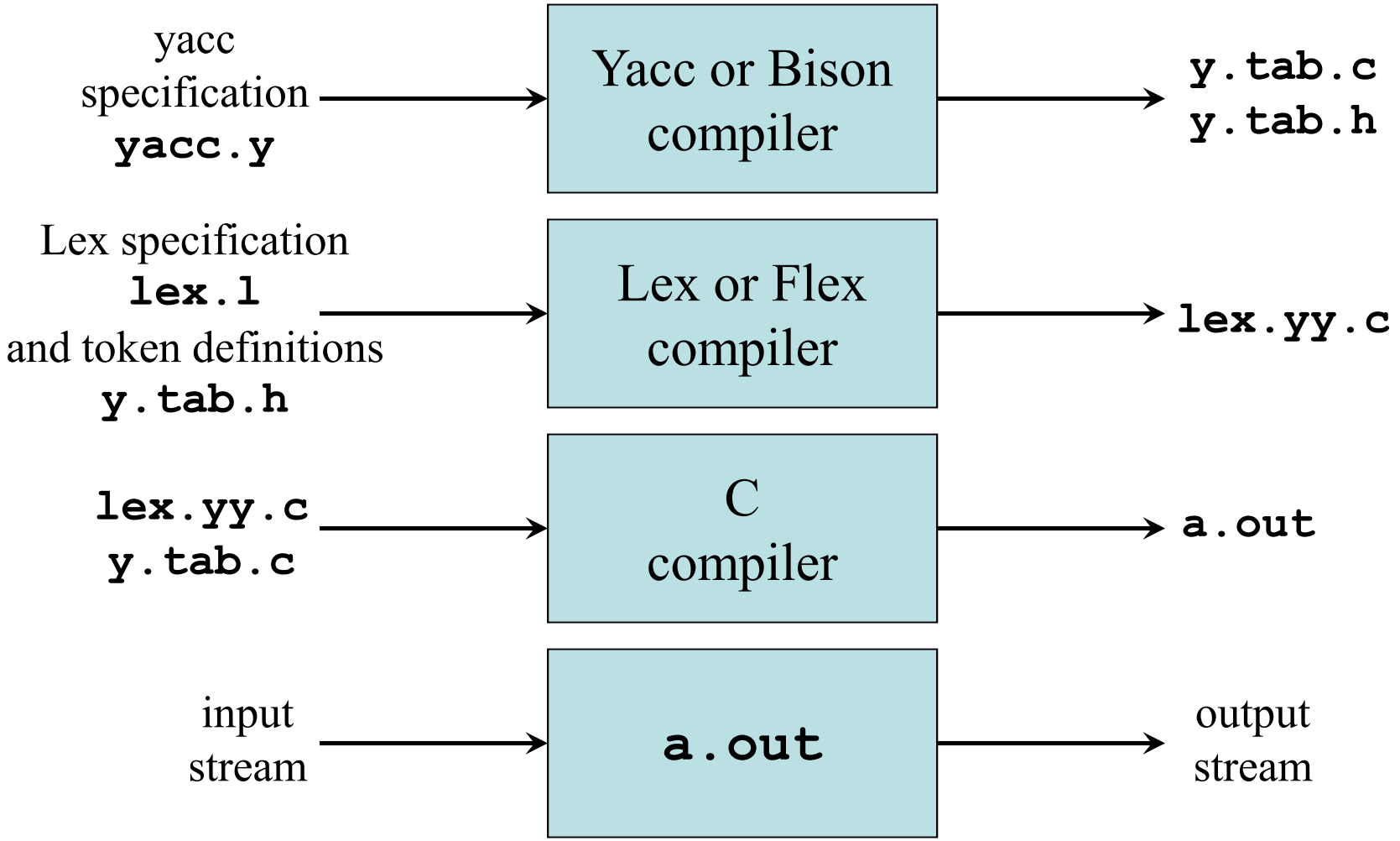
Run the parser

Invoked by parser to report parse errors

Resolve Parsing Action Conflicts

- Two default rules
  - A reduce/reduce conflict is resolved by choosing the conflicting production listed first
  - A shift/reduce conflict is resolved in favor of shift.
- Using precedence and associativity to resolve a shift/ reduce conflict between shifting input symbol **a** and reducing by production $A \rightarrow \alpha$
  - Reduces if the precedence of the production is greater than that of a, or if the precedences are the same and the associativity of the production is left
  - Otherwise, shift

Combining Lex/Flex with Yacc/Bison



Lex Specification for Example 2

```
%option noyywrap
%{
#define YYSTYPE double
#include "y.tab.h"

extern double yylval;
%}
number  [0-9]+\.?|[0-9]*\.[0-9]+
%%
[ ]             { /* skip blanks */ }
{number}        { sscanf(yytext, "%lf", &yylval);
                  return NUMBER;
                }
\n|.            { return yytext[0]; }
```

Generated by Yacc, contains **`#define NUMBER xxx`**

Defined in **`y.tab.c`**

```
yacc -d example2.y
lex example2.l
gcc y.tab.c lex.yy.c
./a.out
```

```
bison -d -y example2.y
flex example2.l
gcc y.tab.c lex.yy.c
./a.out
```

Error Recovery in Yacc

```
%{
…
%}
…
%%
lines   : lines expr '\n'       { printf("%g\n", $2; }
        | lines '\n'
        | /* empty */
        | error '\n'            { yyerror("reenter last line: ");
                                  yyerrok;
                                }
        ;
…
```

Error production:
set error mode and
skip input until newline

Reset parser to normal mode