**Bison**

The Yacc-compatible Parser Generator 26 August 2018, Bison Version 3.1

## by Charles Donnelly and Richard Stallman

This manual (26 August 2018) is for GNU Bison (version 3.1), the GNU parser generator.

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# Table of Contents

Introduction [1](#_bookmark0)

Conditions for Using Bison [3](#_bookmark1)

GNU GENERAL PUBLIC LICENSE [5](#_bookmark2)

1. The Concepts of Bison [17](#_bookmark3)
   1. Languages and Context-Free Grammars [17](#_bookmark3)
   2. From Formal Rules to Bison Input [18](#_bookmark5)
   3. Semantic Values [19](#_bookmark7)
   4. Semantic Actions [20](#_bookmark8)
   5. Writing GLR Parsers [20](#_bookmark8)
      1. Using GLR on Unambiguous Grammars [21](#_bookmark10)
      2. Using GLR to Resolve Ambiguities [23](#_bookmark12)
      3. GLR Semantic Actions [25](#_bookmark13)
         1. Deferred semantic actions [25](#_bookmark13)
         2. YYERROR [26](#_bookmark15)
         3. Restrictions on semantic values and locations [26](#_bookmark15)
      4. Controlling a Parse with Arbitrary Predicates [26](#_bookmark15)
      5. Considerations when Compiling GLR Parsers [27](#_bookmark17)
   6. Locations [27](#_bookmark17)
   7. Bison Output: the Parser Implementation File [28](#_bookmark18)
   8. Stages in Using Bison [29](#_bookmark19)
   9. The Overall Layout of a Bison Grammar [29](#_bookmark19)
2. Examples [31](#_bookmark21)
   1. Reverse Polish Notation Calculator [31](#_bookmark21)
      1. Declarations for rpcalc [31](#_bookmark21)
      2. Grammar Rules for rpcalc [32](#_bookmark24)
         1. Explanation of input [32](#_bookmark24)
         2. Explanation of line [33](#_bookmark25)
         3. Explanation of expr [33](#_bookmark25)
      3. The rpcalc Lexical Analyzer [34](#_bookmark26)
      4. The Controlling Function [35](#_bookmark27)
      5. The Error Reporting Routine [36](#_bookmark28)
      6. Running Bison to Make the Parser [36](#_bookmark28)
      7. Compiling the Parser Implementation File [36](#_bookmark28)
   2. Infix Notation Calculator: calc [37](#_bookmark29)
   3. Simple Error Recovery [38](#_bookmark31)
   4. Location Tracking Calculator: ltcalc [39](#_bookmark32)
      1. Declarations for ltcalc [39](#_bookmark32)
      2. Grammar Rules for ltcalc [40](#_bookmark34)
      3. The ltcalc Lexical Analyzer. [41](#_bookmark35)
   5. Multi-Function Calculator: mfcalc [42](#_bookmark36)
      1. Declarations for mfcalc [43](#_bookmark38)
      2. Grammar Rules for mfcalc [44](#_bookmark40)
      3. The mfcalc Symbol Table [44](#_bookmark40)
      4. The mfcalc Lexer [47](#_bookmark41)
      5. The mfcalc Main [48](#_bookmark42)
   6. Exercises [49](#_bookmark43)
3. Bison Grammar Files [51](#_bookmark44)
   1. Outline of a Bison Grammar [51](#_bookmark44)
      1. The prologue [51](#_bookmark44)
      2. Prologue Alternatives [52](#_bookmark47)
      3. The Bison Declarations Section [56](#_bookmark49)
      4. The Grammar Rules Section [56](#_bookmark49)
      5. The epilogue [57](#_bookmark51)
   2. Symbols, Terminal and Nonterminal [57](#_bookmark51)
   3. Grammar Rules [59](#_bookmark54)
      1. Syntax of Grammar Rules [59](#_bookmark54)
      2. Empty Rules [60](#_bookmark56)
      3. Recursive Rules [60](#_bookmark56)
   4. Defining Language Semantics [61](#_bookmark59)
      1. Data Types of Semantic Values [61](#_bookmark59)
      2. More Than One Value Type [62](#_bookmark62)
      3. Generating the Semantic Value Type [62](#_bookmark62)
      4. The Union Declaration [63](#_bookmark65)
      5. Providing a Structured Semantic Value Type [64](#_bookmark67)
      6. Actions [64](#_bookmark67)
      7. Data Types of Values in Actions [65](#_bookmark69)
      8. Actions in Mid-Rule [66](#_bookmark71)
         1. Using Mid-Rule Actions [66](#_bookmark71)
         2. Typed Mid-Rule Actions [67](#_bookmark73)
         3. Mid-Rule Action Translation [68](#_bookmark75)
         4. Conflicts due to Mid-Rule Actions [70](#_bookmark77)
   5. Tracking Locations [71](#_bookmark78)
      1. Data Type of Locations [71](#_bookmark78)
      2. Actions and Locations [71](#_bookmark78)
      3. Default Action for Locations [73](#_bookmark83)
   6. Named References [74](#_bookmark84)
   7. Bison Declarations [75](#_bookmark86)
      1. Require a Version of Bison [75](#_bookmark86)
      2. Token Type Names [75](#_bookmark86)
      3. Operator Precedence [76](#_bookmark90)
      4. Nonterminal Symbols [77](#_bookmark92)
      5. Performing Actions before Parsing [77](#_bookmark92)
      6. Freeing Discarded Symbols [77](#_bookmark92)
      7. Printing Semantic Values [79](#_bookmark97)
      8. Suppressing Conflict Warnings [80](#_bookmark99)
      9. The Start-Symbol [81](#_bookmark101)
      10. A Pure (Reentrant) Parser [81](#_bookmark101)
      11. A Push Parser [81](#_bookmark101)
      12. Bison Declaration Summary [83](#_bookmark104)
      13. %define Summary [86](#_bookmark108)
      14. %code Summary [92](#_bookmark114)
   8. Multiple Parsers in the Same Program [94](#_bookmark117)
4. Parser C-Language Interface [97](#_bookmark119)
   1. The Parser Function yyparse [97](#_bookmark119)
   2. The Push Parser Function yypush\_parse [98](#_bookmark121)
   3. The Pull Parser Function yypull\_parse [98](#_bookmark121)
   4. The Parser Create Function yystate\_new [98](#_bookmark121)
   5. The Parser Delete Function yystate\_delete [99](#_bookmark125)
   6. The Lexical Analyzer Function yylex [99](#_bookmark125)
      1. Calling Convention for yylex [99](#_bookmark125)
      2. Semantic Values of Tokens [100](#_bookmark128)
      3. Textual Locations of Tokens [101](#_bookmark130)
      4. Calling Conventions for Pure Parsers [101](#_bookmark130)
   7. The Error Reporting Function yyerror [102](#_bookmark133)
   8. Special Features for Use in Actions [103](#_bookmark135)
   9. Parser Internationalization [105](#_bookmark138)
5. The Bison Parser Algorithm [107](#_bookmark140)
   1. Lookahead Tokens [107](#_bookmark140)
   2. Shift/Reduce Conflicts [108](#_bookmark142)
   3. Operator Precedence [109](#_bookmark144)
      1. When Precedence is Needed [109](#_bookmark144)
      2. Specifying Operator Precedence [110](#_bookmark146)
      3. Specifying Precedence Only [110](#_bookmark146)
      4. Precedence Examples [111](#_bookmark147)
      5. How Precedence Works [111](#_bookmark147)
      6. Using Precedence For Non Operators [112](#_bookmark148)
   4. Context-Dependent Precedence [112](#_bookmark148)
   5. Parser States [113](#_bookmark150)
   6. Reduce/Reduce Conflicts [113](#_bookmark150)
   7. Mysterious Conflicts [116](#_bookmark153)
   8. Tuning LR [117](#_bookmark155)
      1. LR Table Construction [118](#_bookmark156)
      2. Default Reductions [119](#_bookmark158)

5.8.3 LAC [121](#_bookmark161)

5.8.4 Unreachable States [122](#_bookmark163)

* 1. Generalized LR (GLR) Parsing [123](#_bookmark165)
  2. Memory Management, and How to Avoid Memory Exhaustion [124](#_bookmark167)

1. Error Recovery [127](#_bookmark170)
2. Handling Context Dependencies [129](#_bookmark172)
   1. Semantic Info in Token Types [129](#_bookmark172)
   2. Lexical Tie-ins [130](#_bookmark174)
   3. Lexical Tie-ins and Error Recovery [131](#_bookmark176)
3. Debugging Your Parser [133](#_bookmark177)
   1. Understanding Your Parser [133](#_bookmark177)
   2. Visualizing Your Parser [140](#_bookmark182)
   3. Visualizing your parser in multiple formats [142](#_bookmark185)
   4. Tracing Your Parser [143](#_bookmark187)
      1. Enabling Traces [143](#_bookmark187)
      2. Enabling Debug Traces for mfcalc [144](#_bookmark190)
      3. The YYPRINT Macro [147](#_bookmark192)
4. Invoking Bison [149](#_bookmark194)
   1. Bison Options [149](#_bookmark194)
   2. Option Cross Key [155](#_bookmark196)
   3. Yacc Library [156](#_bookmark197)
5. Parsers Written In Other Languages [157](#_bookmark198)
   1. C++ Parsers [157](#_bookmark198)
      1. C++ Bison Interface [157](#_bookmark198)
      2. C++ Semantic Values [157](#_bookmark198)
         1. C++ Unions [157](#_bookmark198)
         2. C++ Variants [158](#_bookmark201)
      3. C++ Location Values [159](#_bookmark203)
         1. C++ position [159](#_bookmark203)
         2. C++ location [160](#_bookmark205)
         3. User Defined Location Type [161](#_bookmark206)
      4. C++ Parser Interface [162](#_bookmark208)
      5. C++ Scanner Interface [163](#_bookmark209)
         1. Split Symbols [163](#_bookmark209)
         2. Complete Symbols [164](#_bookmark210)
      6. A Complete C++ Example [165](#_bookmark212)
         1. Calc++ — C++ Calculator [165](#_bookmark212)
         2. Calc++ Parsing Driver [165](#_bookmark212)
         3. Calc++ Parser [167](#_bookmark213)
         4. Calc++ Scanner [169](#_bookmark216)
         5. Calc++ Top Level [171](#_bookmark218)
   2. Java Parsers [172](#_bookmark219)
      1. Java Bison Interface [172](#_bookmark219)
      2. Java Semantic Values [173](#_bookmark221)
      3. Java Location Values [173](#_bookmark221)
      4. Java Parser Interface [174](#_bookmark224)
      5. Java Scanner Interface [175](#_bookmark226)
      6. Special Features for Use in Java Actions [176](#_bookmark228)
      7. Java Push Parser Interface [177](#_bookmark230)
      8. Differences between C/C++ and Java Grammars [178](#_bookmark231)
      9. Java Declarations Summary [179](#_bookmark233)
6. Frequently Asked Questions [183](#_bookmark236)
   1. Memory Exhausted [183](#_bookmark236)
   2. How Can I Reset the Parser [183](#_bookmark236)
   3. Strings are Destroyed [184](#_bookmark237)
   4. Implementing Gotos/Loops [185](#_bookmark238)
   5. Multiple start-symbols [186](#_bookmark239)
   6. Secure? Conform? [186](#_bookmark239)
   7. I can’t build Bison [186](#_bookmark239)
   8. Where can I find help? [187](#_bookmark240)
   9. Bug Reports [187](#_bookmark240)
   10. More Languages [187](#_bookmark240)
   11. Beta Testing [188](#_bookmark241)
   12. Mailing Lists [188](#_bookmark241)

Appendix A Bison Symbols [189](#_bookmark242)

Appendix B Glossary [197](#_bookmark250)

Appendix C GNU Free Documentation License [201](#_bookmark251)

Bibliography [209](#_bookmark252)

Index of Terms [211](#_bookmark253)

# Introduction

*Bison* is a general-purpose parser generator that converts an annotated（注释） context-free grammar into a deterministic LR（一种文法的名称） or generalized LR (GLR) parser employing（使用） LALR(1) parser tables. As an experimental feature, Bison can also generate IELR(1) or canonical LR(1) parser tables. Once you are proficient with Bison, you can use it to develop a wide range of language parsers, from those used in simple desk calculators to complex programming languages.

Bison is upward compatible with Yacc: all properly-written Yacc grammars ought to work with Bison with no change. Anyone familiar with Yacc should be able to use Bison with little trouble. You need to be fluent in C or C++ programming in order to use Bison or to understand this manual. Java is also supported as an experimental feature.

We begin with tutorial chapters that explain the basic concepts of using Bison and show three explained examples, each building on the last. If you don’t know Bison or Yacc, start by reading these chapters. Reference chapters follow, which describe specific aspects of Bison in detail.

Bison was written originally by Robert Corbett. Richard Stallman made it Yacc- compatible. Wilfred Hansen of Carnegie Mellon University added multi-character string literals and other features. Since then, Bison has grown more robust and evolved many other new features thanks to the hard work of a long list of volunteers. For details, see the THANKS and ChangeLog files included in the Bison distribution.

This edition corresponds to version 3.1 of Bison.

# Conditions for Using Bison

The distribution terms for Bison-generated parsers permit（允许） using the parsers in nonfree programs. Before Bison version 2.2, these extra permissions applied only when Bison was generating LALR(1) parsers in C. And before Bison version 1.24, Bison-generated parsers could be used only in programs that were free software.

The other GNU programming tools, such as the GNU C compiler, have never had such a requirement. They could always be used for nonfree software. The reason Bison was different was not due to a special policy decision; it resulted from applying the usual General Public License to all of the Bison source code.

The main output of the Bison utility—the Bison parser implementation file—contains a verbatim（逐字的） copy of a sizable piece of Bison, which is the code for the parser’s implementation. (The actions from your grammar are inserted into this implementation at one point, but most of the rest of the implementation is not changed.) When we applied the GPL terms to the skeleton code for the parser’s implementation, the effect was to restrict the use of Bison output to free software.

We didn’t change the terms because of sympathy for people who want to make software proprietary. **Software should be free.** But we concluded that limiting Bison’s use to free software was doing little to encourage people to make other software free. So we decided to make the practical conditions for using Bison match the practical conditions for using the other GNU tools.

This exception applies when Bison is generating code for a parser. You can tell whether the exception applies to a Bison output file by inspecting the file for text beginning with “As a special exception. . .”. The text spells out the exact terms of the exception.

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Version 3, 29 June 2007

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# The Concepts of Bison

This chapter introduces many of the basic concepts without which the details of Bison will not make sense. If you do not already know how to use Bison or Yacc, we suggest you start by reading this chapter carefully.

## Languages and Context-Free Grammars

In order for Bison to parse a language, it must be described by a *context-free grammar*. This means that you specify one or more *syntactic groupings* and give rules for constructing them from their parts. For example, in the C language, one kind of grouping is called an ‘expression’. One rule for making an expression might be, “An expression can be made of a minus sign and another expression”. Another would be, “An expression can be an integer”. As you can see, rules are often recursive, but there must be at least one rule which leads out of the recursion.

The most common formal system for presenting such rules for humans to read is *Backus- Naur Form* or “BNF”, which was developed in order to specify the language Algol 60. Any grammar expressed in BNF is a context-free grammar. The input to Bison is essentially machine-readable BNF.

There are various important subclasses of context-free grammars. Although it can handle almost all context-free grammars, Bison is optimized for what are called LR(1) grammars. In brief, in these grammars, it must be possible to tell how to parse any portion of an input string with just a single token of lookahead. For historical reasons, Bison by default is limited by the additional restrictions of LALR(1), which is hard to explain simply. See [Section 5.7](#_bookmark154) [[Mysterious Conflicts], page 116](#_bookmark154), for more information on this. As an experimental feature, you can escape these additional restrictions by requesting IELR(1) or canonical LR(1) parser tables. See [Section 5.8.1 [LR Table Construction], page 118](#_bookmark157), to learn how.

Parsers for LR(1) grammars are *deterministic*, meaning roughly that the next grammar rule to apply at any point in the input is uniquely determined by the preceding input and a fixed, finite portion (called a *lookahead*) of the remaining input. A context-free grammar can be *ambiguous*, meaning that there are multiple ways to apply the grammar rules to get the same inputs. Even unambiguous grammars can be *nondeterministic*, meaning that no fixed lookahead always suffices to determine the next grammar rule to apply. With the proper declarations, Bison is also able to parse these more general context-free grammars, using a technique known as GLR parsing (for Generalized LR). Bison’s GLR parsers are able to handle any context-free grammar for which the number of possible parses of any given string is finite.

In the formal grammatical rules for a language, each kind of syntactic unit or grouping is named by a *symbol*. Those which are built by grouping smaller constructs according to grammatical rules are called *nonterminal symbols*; those which can’t be subdivided are called *terminal symbols* or *token types*. We call a piece of input corresponding to a single terminal symbol a *token*, and a piece corresponding to a single nonterminal symbol a *grouping*.

We can use the C language as an example of what symbols, terminal and nonterminal, mean. The tokens of C are identifiers, constants (numeric and string), and the various key- words, arithmetic operators and punctuation marks. So the terminal symbols of a grammar

for C include ‘identifier’, ‘number’, ‘string’, plus one symbol for each keyword, operator or punctuation mark: ‘if’, ‘return’, ‘const’, ‘static’, ‘int’, ‘char’, ‘plus-sign’, ‘open-brace’, ‘close-brace’, ‘comma’ and many more. (These tokens can be subdivided into characters, but that is a matter of lexicography, not grammar.)

Here is a simple C function subdivided into tokens:

int /\* keyword ‘int’ \*/

square (int x) /\* identifier, open-paren, keyword ‘int’,

identifier, close-paren \*/

{ /\* open-brace \*/

return x \* x; /\* keyword ‘return’, identifier, asterisk,

identifier, semicolon \*/

} /\* close-brace \*/

The syntactic groupings of C include the expression, the statement, the declaration, and the function definition. These are represented in the grammar of C by nonterminal symbols ‘expression’, ‘statement’, ‘declaration’ and ‘function definition’. The full grammar uses dozens of additional language constructs, each with its own nonterminal symbol, in order to express the meanings of these four. The example above is a function definition; it contains one declaration, and one statement. In the statement, each ‘x’ is an expression and so is ‘x \* x’.

Each nonterminal symbol must have grammatical rules showing how it is made out of simpler constructs. For example, one kind of C statement is the return statement; this would be described with a grammar rule which reads informally as follows:

A ‘statement’ can be made of a ‘return’ keyword, an ‘expression’ and a ‘semi- colon’.

There would be many other rules for ‘statement’, one for each kind of statement in C. One nonterminal symbol must be distinguished as the special one which defines a com-

plete utterance in the language. It is called the *start symbol*. In a compiler, this means a complete input program. In the C language, the nonterminal symbol ‘sequence of definitions and declarations’ plays this role.

For example, ‘1 + 2’ is a valid C expression—a valid part of a C program—but it is not valid as an *entire* C program. In the context-free grammar of C, this follows from the fact that ‘expression’ is not the start symbol.

The Bison parser reads a sequence of tokens as its input, and groups the tokens using the grammar rules. If the input is valid, the end result is that the entire token sequence reduces to a single grouping whose symbol is the grammar’s start symbol. If we use a grammar for C, the entire input must be a ‘sequence of definitions and declarations’. If not, the parser reports a syntax error.

## From Formal Rules to Bison Input

A formal grammar is a mathematical construct. To define the language for Bison, you must write a file expressing the grammar in Bison syntax: a *Bison grammar* file. See [Chapter 3](#_bookmark44) [[Bison Grammar Files], page 51](#_bookmark44).

A nonterminal symbol in the formal grammar is represented in Bison input as an iden- tifier, like an identifier in C. By convention, it should be in lower case, such as expr, stmt or declaration.

The Bison representation for a terminal symbol is also called a *token type*. Token types as well can be represented as C-like identifiers. By convention, these identifiers should be upper case to distinguish them from nonterminals: for example, INTEGER, IDENTIFIER, IF or RETURN. A terminal symbol that stands for a particular keyword in the language should be named after that keyword converted to upper case. The terminal symbol error is reserved for error recovery. See [Section 3.2 [Symbols], page 57](#_bookmark52).

A terminal symbol can also be represented as a character literal, just like a C character constant. You should do this whenever a token is just a single character (parenthesis, plus-sign, etc.): use that same character in a literal as the terminal symbol for that token.

A third way to represent a terminal symbol is with a C string constant containing several characters. See [Section 3.2 [Symbols], page 57](#_bookmark52), for more information.

The grammar rules also have an expression in Bison syntax. For example, here is the Bison rule for a C return statement. The semicolon in quotes is a literal character token, representing part of the C syntax for the statement; the naked semicolon, and the colon, are Bison punctuation used in every rule.

stmt: RETURN expr ’;’ ;

See [Section 3.3 [Syntax of Grammar Rules], page 59](#_bookmark55).

## Semantic Values

A formal grammar selects tokens only by their classifications: for example, if a rule mentions the terminal symbol ‘integer constant’, it means that *any* integer constant is grammatically valid in that position. The precise value of the constant is irrelevant to how to parse the input: if ‘x+4’ is grammatical then ‘x+1’ or ‘x+3989’ is equally grammatical.

But the precise value is very important for what the input means once it is parsed. A compiler is useless if it fails to distinguish between 4, 1 and 3989 as constants in the program! Therefore, each token in a Bison grammar has both a token type and a *semantic value*. See [Section 3.4 [Defining Language Semantics], page 61](#_bookmark60), for details.

The token type is a terminal symbol defined in the grammar, such as INTEGER, IDENTIFIER or ’,’. It tells everything you need to know to decide where the token may validly appear and how to group it with other tokens. The grammar rules know nothing about tokens except their types.

The semantic value has all the rest of the information about the meaning of the token, such as the value of an integer, or the name of an identifier. (A token such as ’,’ which is just punctuation doesn’t need to have any semantic value.)

For example, an input token might be classified as token type INTEGER and have the semantic value 4. Another input token might have the same token type INTEGER but value 3989. When a grammar rule says that INTEGER is allowed, either of these tokens is acceptable because each is an INTEGER. When the parser accepts the token, it keeps track of the token’s semantic value.

Each grouping can also have a semantic value as well as its nonterminal symbol. For example, in a calculator, an expression typically has a semantic value that is a number. In

a compiler for a programming language, an expression typically has a semantic value that is a tree structure describing the meaning of the expression.

## Semantic Actions

In order to be useful, a program must do more than parse input; it must also produce some output based on the input. In a Bison grammar, a grammar rule can have an *action* made up of C statements. Each time the parser recognizes a match for that rule, the action is executed. See [Section 3.4.6 [Actions], page 64](#_bookmark68).

Most of the time, the purpose of an action is to compute the semantic value of the whole construct from the semantic values of its parts. For example, suppose we have a rule which says an expression can be the sum of two expressions. When the parser recognizes such a sum, each of the subexpressions has a semantic value which describes how it was built up. The action for this rule should create a similar sort of value for the newly recognized larger expression.

For example, here is a rule that says an expression can be the sum of two subexpressions:

expr: expr ’+’ expr { $$ = $1 + $3; } ;

The action says how to produce the semantic value of the sum expression from the values of the two subexpressions.

## Writing GLR Parsers

In some grammars, Bison’s deterministic LR(1) parsing algorithm cannot decide whether to apply a certain grammar rule at a given point. That is, it may not be able to decide (on the basis of the input read so far) which of two possible reductions (applications of a grammar rule) applies, or whether to apply a reduction or read more of the input and apply a reduction later in the input. These are known respectively as *reduce/reduce* conflicts (see [Section 5.6 [Reduce/Reduce], page 113](#_bookmark152)), and *shift/reduce* conflicts (see [Section 5.2](#_bookmark143) [[Shift/Reduce], page 108](#_bookmark143)).

To use a grammar that is not easily modified to be LR(1), a more general parsing algorithm is sometimes necessary. If you include glr-parser among the Bison declarations in your file (see [Section 3.1 [Grammar Outline], page 51](#_bookmark45)), the result is a Generalized LR (GLR) parser. These parsers handle Bison grammars that contain no unresolved conflicts (i.e., after applying precedence declarations) identically to deterministic parsers. However, when faced with unresolved shift/reduce and reduce/reduce conflicts, GLR parsers use the simple expedient of doing both, effectively cloning the parser to follow both possibilities. Each of the resulting parsers can again split, so that at any given time, there can be any number of possible parses being explored. The parsers proceed in lockstep; that is, all of them consume (shift) a given input symbol before any of them proceed to the next. Each of the cloned parsers eventually meets one of two possible fates: either it runs into a parsing error, in which case it simply vanishes, or it merges with another parser, because the two of them have reduced the input to an identical set of symbols.

During the time that there are multiple parsers, semantic actions are recorded, but not performed. When a parser disappears, its recorded semantic actions disappear as well, and are never performed. When a reduction makes two parsers identical, causing them to merge, Bison records both sets of semantic actions. Whenever the last two parsers merge, reverting

to the single-parser case, Bison resolves all the outstanding actions either by precedences given to the grammar rules involved, or by performing both actions, and then calling a designated user-defined function on the resulting values to produce an arbitrary merged result.

#### Using GLR on Unambiguous Grammars

In the simplest cases, you can use the GLR algorithm to parse grammars that are unam- biguous but fail to be LR(1). Such grammars typically require more than one symbol of lookahead.

Consider a problem that arises in the declaration of enumerated and subrange types in the programming language Pascal. Here are some examples:

type subrange = lo .. hi; type enum = (a, b, c);

The original language standard allows only numeric literals and constant identifiers for the subrange bounds (‘lo’ and ‘hi’), but Extended Pascal (ISO/IEC 10206) and many other Pascal implementations allow arbitrary expressions there. This gives rise to the following situation, containing a superfluous pair of parentheses:

type subrange = (a) .. b;

Compare this to the following declaration of an enumerated type with only one value:

type enum = (a);

(These declarations are contrived, but they are syntactically valid, and more-complicated cases can come up in practical programs.)

These two declarations look identical until the ‘..’ token. With normal LR(1) one-token lookahead it is not possible to decide between the two forms when the identifier ‘a’ is parsed. It is, however, desirable for a parser to decide this, since in the latter case ‘a’ must become a new identifier to represent the enumeration value, while in the former case ‘a’ must be evaluated with its current meaning, which may be a constant or even a function call.

You could parse ‘(a)’ as an “unspecified identifier in parentheses”, to be resolved later, but this typically requires substantial contortions in both semantic actions and large parts of the grammar, where the parentheses are nested in the recursive rules for expressions.

You might think of using the lexer to distinguish between the two forms by returning different tokens for currently defined and undefined identifiers. But if these declarations occur in a local scope, and ‘a’ is defined in an outer scope, then both forms are possible— either locally redefining ‘a’, or using the value of ‘a’ from the outer scope. So this approach cannot work.

A simple solution to this problem is to declare the parser to use the GLR algorithm. When the GLR parser reaches the critical state, it merely splits into two branches and pursues both syntax rules simultaneously. Sooner or later, one of them runs into a parsing error. If there is a ‘..’ token before the next ‘;’, the rule for enumerated types fails since it cannot accept ‘..’ anywhere; otherwise, the subrange type rule fails since it requires a ‘..’ token. So one of the branches fails silently, and the other one continues normally, performing all the intermediate actions that were postponed during the split.

If the input is syntactically incorrect, both branches fail and the parser reports a syntax error as usual.

The effect of all this is that the parser seems to “guess” the correct branch to take, or in other words, it seems to use more lookahead than the underlying LR(1) algorithm actually allows for. In this example, LR(2) would suffice, but also some cases that are not LR(*k*) for any *k* can be handled this way.

In general, a GLR parser can take quadratic or cubic worst-case time, and the current Bison parser even takes exponential time and space for some grammars. In practice, this rarely happens, and for many grammars it is possible to prove that it cannot happen. The present example contains only one conflict between two rules, and the type-declaration context containing the conflict cannot be nested. So the number of branches that can exist at any time is limited by the constant 2, and the parsing time is still linear.

Here is a Bison grammar corresponding to the example above. It parses a vastly simpli- fied form of Pascal type declarations.

token TYPE DOTDOT ID

left ’+’ ’-’

left ’\*’ ’/’



type\_decl: TYPE ID ’=’ type ’;’ ;

type:

’(’ id\_list ’)’

| expr DOTDOT expr

;

id\_list:

ID

| id\_list ’,’ ID

;

expr:

’(’ expr ’)’

| expr ’+’ expr

| expr ’-’ expr

| expr ’\*’ expr

| expr ’/’ expr

| ID

;

When used as a normal LR(1) grammar, Bison correctly complains about one reduce/reduce conflict. In the conflicting situation the parser chooses one of the alternatives, arbitrarily the one declared first. Therefore the following correct input is not recognized:

type t = (a) .. b;

The parser can be turned into a GLR parser, while also telling Bison to be silent about the one known reduce/reduce conflict, by adding these two declarations to the Bison grammar file (before the first ‘ ’):



glr-parser expect-rr 1

No change in the grammar itself is required. Now the parser recognizes all valid declarations, according to the limited syntax above, transparently. In fact, the user does not even notice when the parser splits.

So here we have a case where we can use the benefits of GLR, almost without disad- vantages. Even in simple cases like this, however, there are at least two potential problems to beware. First, always analyze the conflicts reported by Bison to make sure that GLR splitting is only done where it is intended. A GLR parser splitting inadvertently may cause problems less obvious than an LR parser statically choosing the wrong alternative in a conflict. Second, consider interactions with the lexer (see [Section 7.1 [Semantic Tokens],](#_bookmark173) [page 129](#_bookmark173)) with great care. Since a split parser consumes tokens without performing any actions during the split, the lexer cannot obtain information via parser actions. Some cases of lexer interactions can be eliminated by using GLR to shift the complications from the lexer to the parser. You must check the remaining cases for correctness.

In our example, it would be safe for the lexer to return tokens based on their current meanings in some symbol table, because no new symbols are defined in the middle of a type declaration. Though it is possible for a parser to define the enumeration constants as they are parsed, before the type declaration is completed, it actually makes no difference since they cannot be used within the same enumerated type declaration.

#### Using GLR to Resolve Ambiguities

Let’s consider an example, vastly simplified from a C++ grammar.

{

#include <stdio.h>

#define YYSTYPE char const \* int yylex (void);

void yyerror (char const \*); }

token TYPENAME ID

right ’=’ left ’+’

glr-parser



prog:

empty

| prog stmt { printf ("\n"); }

;

stmt:

expr ’;’ dprec 1

| decl dprec 2

;

expr:

ID { printf (" s ", $$); }

| TYPENAME ’(’ expr ’)’

{ printf ("s <cast> ", $1); }

| expr ’+’ expr { printf ("+ "); }

| expr ’=’ expr { printf ("= "); }

;

decl:

TYPENAME declarator ’;’

{ printf ("s <declare> ", $1); }

| TYPENAME declarator ’=’ expr ’;’

{ printf ("s <init-declare> ", $1); }

;

declarator:

ID { printf ("\" s\" ", $1); }

| ’(’ declarator ’)’

;

This models a problematic part of the C++ grammar—the ambiguity between certain dec- larations and statements. For example,

T (x) = y+z;

parses as either an expr or a stmt (assuming that ‘T’ is recognized as a TYPENAME and ‘x’ as an ID). Bison detects this as a reduce/reduce conflict between the rules expr : ID and declarator : ID, which it cannot resolve at the time it encounters x in the example above. Since this is a GLR parser, it therefore splits the problem into two parses, one for each choice of resolving the reduce/reduce conflict. Unlike the example from the previous section (see [Section 1.5.1 [Simple GLR Parsers], page 21](#_bookmark11)), however, neither of these parses “dies,” because the grammar as it stands is ambiguous. One of the parsers eventually reduces stmt

: expr ’;’ and the other reduces stmt : decl, after which both parsers are in an identical state: they’ve seen ‘prog stmt’ and have the same unprocessed input remaining. We say that these parses have *merged.*

At this point, the GLR parser requires a specification in the grammar of how to choose between the competing parses. In the example above, the two dprec declarations specify that Bison is to give precedence to the parse that interprets the example as a decl, which implies that x is a declarator. The parser therefore prints

"x" y z + T <init-declare>

The dprec declarations only come into play when more than one parse survives. Con- sider a different input string for this parser:

T (x) + y;

This is another example of using GLR to parse an unambiguous construct, as shown in the previous section (see [Section 1.5.1 [Simple GLR Parsers], page 21](#_bookmark11)). Here, there is no

ambiguity (this cannot be parsed as a declaration). However, at the time the Bison parser encounters x, it does not have enough information to resolve the reduce/reduce conflict (again, between x as an expr or a declarator). In this case, no precedence declaration is used. Again, the parser splits into two, one assuming that x is an expr, and the other assuming x is a declarator. The second of these parsers then vanishes when it sees +, and the parser prints

x T <cast> y +

Suppose that instead of resolving the ambiguity, you wanted to see all the possibilities. For this purpose, you must merge the semantic actions of the two possible parsers, rather than choosing one over the other. To do so, you could change the declaration of stmt as follows:

stmt:

expr ’;’ merge <stmtMerge>

| decl merge <stmtMerge>

;

and define the stmtMerge function as:

static YYSTYPE

stmtMerge (YYSTYPE x0, YYSTYPE x1)

{

printf ("<OR> "); return "";

}

with an accompanying forward declaration in the C declarations at the beginning of the file:

{

#define YYSTYPE char const \*

static YYSTYPE stmtMerge (YYSTYPE x0, YYSTYPE x1); }

With these declarations, the resulting parser parses the first example as both an expr and a decl, and prints

"x" y z + T <init-declare> x T <cast> y z + = <OR>

Bison requires that all of the productions that participate in any particular merge have identical ‘merge’ clauses. Otherwise, the ambiguity would be unresolvable, and the parser will report an error during any parse that results in the offending merge.

#### GLR Semantic Actions

The nature of GLR parsing and the structure of the generated parsers give rise to certain restrictions on semantic values and actions.

#### Deferred semantic actions

By definition, a deferred semantic action is not performed at the same time as the associated reduction. This raises caveats for several Bison features you might use in a semantic action in a GLR parser.

In any semantic action, you can examine yychar to determine the type of the lookahead token present at the time of the associated reduction. After checking that yychar is not set

to YYEMPTY or YYEOF, you can then examine yylval and yylloc to determine the lookahead token’s semantic value and location, if any. In a nondeferred semantic action, you can also modify any of these variables to influence syntax analysis. See [Section 5.1 [Lookahead](#_bookmark141) [Tokens], page 107](#_bookmark141).

In a deferred semantic action, it’s too late to influence syntax analysis. In this case, yychar, yylval, and yylloc are set to shallow copies of the values they had at the time of the associated reduction. For this reason alone, modifying them is dangerous. Moreover, the result of modifying them is undefined and subject to change with future versions of Bison. For example, if a semantic action might be deferred, you should never write it to invoke yyclearin (see [Section 4.8 [Action Features], page 103](#_bookmark136)) or to attempt to free memory referenced by yylval.

#### YYERROR

Another Bison feature requiring special consideration is YYERROR (see [Section 4.8 [Action](#_bookmark136) [Features], page 103](#_bookmark136)), which you can invoke in a semantic action to initiate error recovery. During deterministic GLR operation, the effect of YYERROR is the same as its effect in a deterministic parser. The effect in a deferred action is similar, but the precise point of the error is undefined; instead, the parser reverts to deterministic operation, selecting an unspecified stack on which to continue with a syntax error. In a semantic predicate (see [Section 1.5.4 [Semantic Predicates], page 26](#_bookmark16)) during nondeterministic parsing, YYERROR silently prunes the parse that invoked the test.

#### Restrictions on semantic values and locations

GLR parsers require that you use POD (Plain Old Data) types for semantic values and location types when using the generated parsers as C++ code.

#### Controlling a Parse with Arbitrary Predicates

In addition to the dprec and merge directives, GLR parsers allow you to reject parses on the basis of arbitrary computations executed in user code, without having Bison treat this rejection as an error if there are alternative parses. (This feature is experimental and may evolve. We welcome user feedback.) For example,

widget:

?{ new\_syntax } "widget" id new\_args { $$ = f($3, $4); }

| ?{ !new\_syntax } "widget" id old\_args { $$ = f($3, $4); }

;

is one way to allow the same parser to handle two different syntaxes for widgets. The clause preceded by ? is treated like an ordinary action, except that its text is treated as an expression and is always evaluated immediately (even when in nondeterministic mode). If the expression yields 0 (false), the clause is treated as a syntax error, which, in a nonde- terministic parser, causes the stack in which it is reduced to die. In a deterministic parser, it acts like YYERROR.

As the example shows, predicates otherwise look like semantic actions, and therefore you must be take them into account when determining the numbers to use for denoting the semantic values of right-hand side symbols. Predicate actions, however, have no defined value, and may not be given labels.

There is a subtle difference between semantic predicates and ordinary actions in nonde- terministic mode, since the latter are deferred. For example, we could try to rewrite the previous example as

widget:

{ if (!new\_syntax) YYERROR; }

"widget" id new\_args { $$ = f($3, $4); }

| { if (new\_syntax) YYERROR; }

"widget" id old\_args { $$ = f($3, $4); }

;

(reversing the sense of the predicate tests to cause an error when they are false). However, this does *not* have the same effect if new\_args and old\_args have overlapping syntax. Since the mid-rule actions testing new\_syntax are deferred, a GLR parser first encounters the unresolved ambiguous reduction for cases where new\_args and old\_args recognize the same string *before* performing the tests of new\_syntax. It therefore reports an error.

Finally, be careful in writing predicates: deferred actions have not been evaluated, so that using them in a predicate will have undefined effects.

#### Considerations when Compiling GLR Parsers

The GLR parsers require a compiler for ISO C89 or later. In addition, they use the inline keyword, which is not C89, but is C99 and is a common extension in pre-C99 compilers. It is up to the user of these parsers to handle portability issues. For instance, if using Autoconf and the Autoconf macro AC\_C\_INLINE, a mere

{

#include <config.h> }

will suffice. Otherwise, we suggest

{

#if ( STDC\_VERSION < 199901 && ! defined GNUC \ && ! defined inline)

# define inline #endif

}

## Locations

Many applications, like interpreters or compilers, have to produce verbose and useful error messages. To achieve this, one must be able to keep track of the *textual location*, or *location*, of each syntactic construct. Bison provides a mechanism for handling these locations.

Each token has a semantic value. In a similar fashion, each token has an associated location, but the type of locations is the same for all tokens and groupings. Moreover, the output parser is equipped with a default data structure for storing locations (see [Section 3.5](#_bookmark79) [[Tracking Locations], page 71](#_bookmark79), for more details).

Like semantic values, locations can be reached in actions using a dedicated set of con- structs. In the example above, the location of the whole grouping is @$, while the locations of the subexpressions are @1 and @3.

When a rule is matched, a default action is used to compute the semantic value of its left hand side (see [Section 3.4.6 [Actions], page 64](#_bookmark68)). In the same way, another default action is used for locations. However, the action for locations is general enough for most cases, meaning there is usually no need to describe for each rule how @$ should be formed. When building a new location for a given grouping, the default behavior of the output parser is to take the beginning of the first symbol, and the end of the last symbol.

## Bison Output: the Parser Implementation File

When you run Bison, you give it a Bison grammar file as input. The most important output is a C source file that implements a parser for the language described by the grammar. This parser is called a *Bison parser*, and this file is called a *Bison parser implementation file*. Keep in mind that the Bison utility and the Bison parser are two distinct programs: the Bison utility is a program whose output is the Bison parser implementation file that becomes part of your program.

The job of the Bison parser is to group tokens into groupings according to the grammar rules—for example, to build identifiers and operators into expressions. As it does this, it runs the actions for the grammar rules it uses.

The tokens come from a function called the *lexical analyzer* that you must supply in some fashion (such as by writing it in C). The Bison parser calls the lexical analyzer each time it wants a new token. It doesn’t know what is “inside” the tokens (though their semantic values may reflect this). Typically the lexical analyzer makes the tokens by parsing characters of text, but Bison does not depend on this. See [Section 4.6 [The Lexical Analyzer Function](#_bookmark126) [yylex], page 99](#_bookmark126).

The Bison parser implementation file is C code which defines a function named yyparse which implements that grammar. This function does not make a complete C program: you must supply some additional functions. One is the lexical analyzer. Another is an error-reporting function which the parser calls to report an error. In addition, a complete C program must start with a function called main; you have to provide this, and arrange for it to call yyparse or the parser will never run. See [Chapter 4 [Parser C-Language Interface],](#_bookmark119) [page 97](#_bookmark119).

Aside from the token type names and the symbols in the actions you write, all symbols defined in the Bison parser implementation file itself begin with ‘yy’ or ‘YY’. This includes interface functions such as the lexical analyzer function yylex, the error reporting function yyerror and the parser function yyparse itself. This also includes numerous identifiers used for internal purposes. Therefore, you should avoid using C identifiers starting with ‘yy’ or ‘YY’ in the Bison grammar file except for the ones defined in this manual. Also, you should avoid using the C identifiers ‘malloc’ and ‘free’ for anything other than their usual meanings.

In some cases the Bison parser implementation file includes system headers, and in those cases your code should respect the identifiers reserved by those headers. On some non-GNU hosts, <alloca.h>, <malloc.h>, <stddef.h>, and <stdlib.h> are included as needed to declare memory allocators and related types. <libintl.h> is included if message translation is in use (see [Section 4.9 [Internationalization], page 105](#_bookmark139)). Other system headers may be included if you define YYDEBUG to a nonzero value (see [Section 8.4 [Tracing Your](#_bookmark188) [Parser], page 143](#_bookmark188)).

## Stages in Using Bison

The actual language-design process using Bison, from grammar specification to a working compiler or interpreter, has these parts:

1. Formally specify the grammar in a form recognized by Bison (see [Chapter 3 [Bison Grammar Files], page 51](#_bookmark44)). For each grammatical rule in the language, describe the action that is to be taken when an instance of that rule is recognized. The action is described by a sequence of C statements.
2. Write a lexical analyzer to process input and pass tokens to the parser. The lexical analyzer may be written by hand in C (see [Section 4.6 [The Lexical Analyzer Function yylex], page 99](#_bookmark126)). It could also be produced using Lex, but the use of Lex is not discussed in this manual.
3. Write a controlling function that calls the Bison-produced parser.
4. Write error-reporting routines.

To turn this source code as written into a runnable program, you must follow these steps:

1. Run Bison on the grammar to produce the parser.
2. Compile the code output by Bison, as well as any other source files.
3. Link the object files to produce the finished product.

## The Overall Layout of a Bison Grammar

The input file for the Bison utility is a *Bison grammar file*. The general form of a Bison grammar file is as follows:

{

*Prologue*

}

*Bison declarations*



*Grammar rules*



*Epilogue*

The ‘ ’, ‘{’ and ‘}’ are punctuation that appears in every Bison grammar file to separate the sections.



The prologue may define types and variables used in the actions. You can also use preprocessor commands to define macros used there, and use #include to include header files that do any of these things. You need to declare the lexical analyzer yylex and the error printer yyerror here, along with any other global identifiers used by the actions in the grammar rules.

The Bison declarations declare the names of the terminal and nonterminal symbols, and may also describe operator precedence and the data types of semantic values of various symbols.

The grammar rules define how to construct each nonterminal symbol from its parts.

The epilogue can contain any code you want to use. Often the definitions of functions declared in the prologue go here. In a simple program, all the rest of the program can go here.

# Examples

Now we show and explain several sample programs written using Bison: a Reverse Polish Notation calculator, an algebraic (infix) notation calculator — later extended to track “lo- cations” — and a multi-function calculator. All produce usable, though limited, interactive desk-top calculators.

These examples are simple, but Bison grammars for real programming languages are written the same way. You can copy these examples into a source file to try them.

## Reverse Polish Notation Calculator

The first example is that of a simple double-precision *Reverse Polish Notation* calculator (a calculator using postfix operators). This example provides a good starting point, since oper- ator precedence is not an issue. The second example will illustrate how operator precedence is handled.

The source code for this calculator is named rpcalc.y. The ‘.y’ extension is a convention used for Bison grammar files.

* + 1. **Declarations for** rpcalc

Here are the C and Bison declarations for the Reverse Polish Notation calculator. As in C, comments are placed between ‘/\*...\*/’.

/\* Reverse Polish Notation calculator. \*/

{

#include <stdio.h> #include <math.h> int yylex (void);

void yyerror (char const \*); }

define api.value.type {double} token NUM

/\* Grammar rules and actions follow. \*/



The declarations section (see [Section 3.1.1 [The prologue], page 51](#_bookmark46)) contains two pre- processor directives and two forward declarations.

The #include directive is used to declare the exponentiation function pow.

The forward declarations for yylex and yyerror are needed because the C language requires that functions be declared before they are used. These functions will be defined in the epilogue, but the parser calls them so they must be declared in the prologue.

The second section, Bison declarations, provides information to Bison about the tokens and their types (see [Section 3.1.3 [The Bison Declarations Section], page 56](#_bookmark50)).

The define directive defines the variable api.value.type, thus specifying the C data type for semantic values of both tokens and groupings (see [Section 3.4.1 [Data Types of](#_bookmark61) [Semantic Values], page 61](#_bookmark61)). The Bison parser will use whatever type api.value.type is

defined as; if you don’t define it, int is the default. Because we specify ‘{double}’, each token and each expression has an associated value, which is a floating point number. C code can use YYSTYPE to refer to the value api.value.type.

Each terminal symbol that is not a single-character literal must be declared. (Single- character literals normally don’t need to be declared.) In this example, all the arithmetic operators are designated by single-character literals, so the only terminal symbol that needs to be declared is NUM, the token type for numeric constants.

* + 1. **Grammar Rules for** rpcalc

Here are the grammar rules for the Reverse Polish Notation calculator.

input:

empty

| input line

;

line:

’\n’

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| | exp  ; | ’\n’ |  | { | printf (".10g\n", | $1); } |  |
| exp:  NUM |  |  | { | $$ = $1; | } |
| | exp | exp | ’+’ | { | $$ = $1 + $2; | } |
| | exp | exp | ’-’ | { | $$ = $1 - $2; | } |
| | exp | exp | ’\*’ | { | $$ = $1 \* $2; | } |
| | exp | exp | ’/’ | { | $$ = $1 / $2; | } |
| | exp | exp | ’^’ | { | $$ = pow ($1, $2); | } /\* Exponentiation | \*/ |
| | exp  ; | ’n’ |  | { | $$ = -$1; | } /\* Unary minus | \*/ |



The groupings of the rpcalc “language” defined here are the expression (given the name exp), the line of input (line), and the complete input transcript (input). Each of these nonterminal symbols has several alternate rules, joined by the vertical bar ‘|’ which is read as “or”. The following sections explain what these rules mean.

The semantics of the language is determined by the actions taken when a grouping is recognized. The actions are the C code that appears inside braces. See [Section 3.4.6](#_bookmark68) [[Actions], page 64](#_bookmark68).

You must specify these actions in C, but Bison provides the means for passing semantic values between the rules. In each action, the pseudo-variable $$ stands for the semantic value for the grouping that the rule is going to construct. Assigning a value to $$ is the main job of most actions. The semantic values of the components of the rule are referred to as $1, $2, and so on.

* + - 1. **Explanation of** input

Consider the definition of input: input:

empty

| input line

;

This definition reads as follows: “A complete input is either an empty string, or a complete input followed by an input line”. Notice that “complete input” is defined in terms of itself. This definition is said to be *left recursive* since input appears always as the leftmost symbol in the sequence. See [Section 3.3.3 [Recursive Rules], page 60](#_bookmark58).

The first alternative is empty because there are no symbols between the colon and the first ‘|’; this means that input can match an empty string of input (no tokens). We write the rules this way because it is legitimate to type *Ctrl-d* right after you start the calculator. It’s conventional to put an empty alternative first and to use the (optional) empty directive, or to write the comment ‘/\* empty \*/’ in it (see [Section 3.3.2 [Empty Rules], page 60](#_bookmark57)).

The second alternate rule (input line) handles all nontrivial input. It means, “After reading any number of lines, read one more line if possible.” The left recursion makes this rule into a loop. Since the first alternative matches empty input, the loop can be executed zero or more times.

The parser function yyparse continues to process input until a grammatical error is seen or the lexical analyzer says there are no more input tokens; we will arrange for the latter to happen at end-of-input.

* + - 1. **Explanation of** line

Now consider the definition of line: line:

’\n’

| exp ’\n’ { printf (" .10g\n", $1); }

;

The first alternative is a token which is a newline character; this means that rpcalc accepts a blank line (and ignores it, since there is no action). The second alternative is an expression followed by a newline. This is the alternative that makes rpcalc useful. The semantic value of the exp grouping is the value of $1 because the exp in question is the first symbol in the alternative. The action prints this value, which is the result of the computation the user asked for.

This action is unusual because it does not assign a value to $$. As a consequence, the semantic value associated with the line is uninitialized (its value will be unpredictable). This would be a bug if that value were ever used, but we don’t use it: once rpcalc has printed the value of the user’s input line, that value is no longer needed.

* + - 1. **Explanation of** expr

The exp grouping has several rules, one for each kind of expression. The first rule handles the simplest expressions: those that are just numbers. The second handles an addition- expression, which looks like two expressions followed by a plus-sign. The third handles subtraction, and so on.

exp:

NUM

| exp exp ’+’ { $$ = $1 + $2; }

| exp exp ’-’ { $$ = $1 - $2; }

...

;

We have used ‘|’ to join all the rules for exp, but we could equally well have written them separately:

exp: NUM ;

exp: exp exp ’+’ { $$ = $1 + $2; }; exp: exp exp ’-’ { $$ = $1 - $2; };

...

Most of the rules have actions that compute the value of the expression in terms of the value of its parts. For example, in the rule for addition, $1 refers to the first component exp and $2 refers to the second one. The third component, ’+’, has no meaningful associated semantic value, but if it had one you could refer to it as $3. When yyparse recognizes a sum expression using this rule, the sum of the two subexpressions’ values is produced as the value of the entire expression. See [Section 3.4.6 [Actions], page 64](#_bookmark68).

You don’t have to give an action for every rule. When a rule has no action, Bison by default copies the value of $1 into $$. This is what happens in the first rule (the one that uses NUM).

The formatting shown here is the recommended convention, but Bison does not require it. You can add or change white space as much as you wish. For example, this:

exp: NUM | exp exp ’+’ {$$ = $1 + $2; } | ... ;

means the same thing as this:

exp:

NUM

| exp exp ’+’ { $$ = $1 + $2; }

| ...

;

The latter, however, is much more readable.

* + 1. **The** rpcalc **Lexical Analyzer**

The lexical analyzer’s job is low-level parsing: converting characters or sequences of char- acters into tokens. The Bison parser gets its tokens by calling the lexical analyzer. See [Section 4.6 [The Lexical Analyzer Function yylex], page 99](#_bookmark126).

Only a simple lexical analyzer is needed for the RPN calculator. This lexical analyzer skips blanks and tabs, then reads in numbers as double and returns them as NUM tokens. Any other character that isn’t part of a number is a separate token. Note that the token- code for such a single-character token is the character itself.

The return value of the lexical analyzer function is a numeric code which represents a token type. The same text used in Bison rules to stand for this token type is also a C expression for the numeric code for the type. This works in two ways. If the token type is a character literal, then its numeric code is that of the character; you can use the same character literal in the lexical analyzer to express the number. If the token type is an identifier, that identifier is defined by Bison as a C macro whose definition is the appropriate number. In this example, therefore, NUM becomes a macro for yylex to use.

The semantic value of the token (if it has one) is stored into the global variable yylval, which is where the Bison parser will look for it. (The C data type of yylval is YYSTYPE, whose value was defined at the beginning of the grammar via ‘ define api.value.type

{double}’; see [Section 2.1.1 [Declarations for rpcalc], page 31](#_bookmark23).)

A token type code of zero is returned if the end-of-input is encountered. (Bison recognizes any nonpositive value as indicating end-of-input.)

Here is the code for the lexical analyzer:

/\* The lexical analyzer returns a double floating point number on the stack and the token NUM, or the numeric code of the character read if not a number. It skips all blanks and tabs, and returns 0 for end-of-input. \*/

#include <ctype.h> int

yylex (void)

{

int c;

/\* Skip white space. \*/

while ((c = getchar ()) == ’ ’ || c == ’\t’) continue;

/\* Process numbers. \*/

if (c == ’.’ || isdigit (c))

{

ungetc (c, stdin); scanf ("lf", &yylval); return NUM;

}

/\* Return end-of-input. \*/ if (c == EOF)

return 0;

/\* Return a single char. \*/ return c;

}

#### The Controlling Function

In keeping with the spirit of this example, the controlling function is kept to the bare minimum. The only requirement is that it call yyparse to start the process of parsing.

int

main (void)

{

return yyparse ();

}

#### The Error Reporting Routine

When yyparse detects a syntax error, it calls the error reporting function yyerror to print an error message (usually but not always "syntax error"). It is up to the programmer to supply yyerror (see [Chapter 4 [Parser C-Language Interface], page 97](#_bookmark119)), so here is the definition we will use:

#include <stdio.h>

/\* Called by yyparse on error. \*/ void

yyerror (char const \*s)

{

fprintf (stderr, "s\n", s);

}

After yyerror returns, the Bison parser may recover from the error and continue parsing if the grammar contains a suitable error rule (see [Chapter 6 [Error Recovery], page 127](#_bookmark170)). Otherwise, yyparse returns nonzero. We have not written any error rules in this example, so any invalid input will cause the calculator program to exit. This is not clean behavior for a real calculator, but it is adequate for the first example.

#### Running Bison to Make the Parser

Before running Bison to produce a parser, we need to decide how to arrange all the source code in one or more source files. For such a simple example, the easiest thing is to put everything in one file, the grammar file. The definitions of yylex, yyerror and main go at the end, in the epilogue of the grammar file (see [Section 1.9 [The Overall Layout of a Bison](#_bookmark20) [Grammar], page 29](#_bookmark20)).

For a large project, you would probably have several source files, and use make to arrange to recompile them.

With all the source in the grammar file, you use the following command to convert it into a parser implementation file:

bison *file*.y

In this example, the grammar file is called rpcalc.y (for “Reverse Polish calculator”). Bison produces a parser implementation file named *file*.tab.c, removing the ‘.y’ from the grammar file name. The parser implementation file contains the source code for yyparse. The additional functions in the grammar file (yylex, yyerror and main) are copied verbatim to the parser implementation file.

#### Compiling the Parser Implementation File

Here is how to compile and run the parser implementation file:

# List files in current directory.

$ *ls*

rpcalc.tab.c rpcalc.y

# Compile the Bison parser.

# ‘-lm’ tells compiler to search math library for pow.

$ *cc -lm -o rpcalc rpcalc.tab.c*

# List files again.

$ *ls*

rpcalc rpcalc.tab.c rpcalc.y

The file rpcalc now contains the executable code. Here is an example session using

rpcalc.

$ *rpcalc 4 9* +

*⇒* 13

*3 7* + *3 4 5 \**+*-*

*⇒* -13

1. *7* + *3 4 5 \** + *- n* Note the unary minus, ‘n’

*⇒* 13

*5 6 / 4 n* +

*⇒* -3.166666667

*3 4* ^ Exponentiation

*⇒* 81

^*D* End-of-file indicator

$

## Infix Notation Calculator: calc

We now modify rpcalc to handle infix operators instead of postfix. Infix notation involves the concept of operator precedence and the need for parentheses nested to arbitrary depth. Here is the Bison code for calc.y, an infix desk-top calculator.

/\* Infix notation calculator. \*/

{

#include <math.h> #include <stdio.h> int yylex (void);

void yyerror (char const \*); }

/\* Bison declarations. \*/ define api.value.type {double} token NUM

left ’-’ ’+’

left ’\*’ ’/’

precedence NEG /\* negation--unary minus \*/ right ’^’ /\* exponentiation \*/

/\* The grammar follows. \*/ input:



empty

| input line

;

line:

’\n’

| exp ’\n’ { printf ("\t.10g\n", $1); }

;

exp:

NUM { $$ = $1; }

| exp ’+’ exp { $$ = $1 + $3; }

| exp ’-’ exp { $$ = $1 - $3; }

| exp ’\*’ exp { $$ = $1 \* $3; }

| exp ’/’ exp { $$ = $1 / $3; }

| ’-’ exp prec NEG { $$ = -$2; }

| exp ’^’ exp { $$ = pow ($1, $3); }

| ’(’ exp ’)’ { $$ = $2; }

;



The functions yylex, yyerror and main can be the same as before.

There are two important new features shown in this code.

In the second section (Bison declarations), left declares token types and says they are left-associative operators. The declarations left and right (right associativity) take the place of token which is used to declare a token type name without associativity/precedence. (These tokens are single-character literals, which ordinarily don’t need to be declared. We declare them here to specify the associativity/precedence.)

Operator precedence is determined by the line ordering of the declarations; the higher the line number of the declaration (lower on the page or screen), the higher the precedence. Hence, exponentiation has the highest precedence, unary minus (NEG) is next, followed by ‘\*’ and ‘/’, and so on. Unary minus is not associative, only precedence matters (precedence. See [Section 5.3 [Operator Precedence], page 109](#_bookmark145).

The other important new feature is the prec in the grammar section for the unary minus operator. The prec simply instructs Bison that the rule ‘| ’-’ exp’ has the same precedence as NEG—in this case the next-to-highest. See [Section 5.4 [Context-Dependent](#_bookmark149) [Precedence], page 112](#_bookmark149).

Here is a sample run of calc.y:

$ *calc*

*4* + *4.5 - (34/(8\*3*+*-3))*

6.880952381

*-56* + *2*

-54

*3* ^ *2*

9

## Simple Error Recovery

Up to this point, this manual has not addressed the issue of *error recovery*—how to continue parsing after the parser detects a syntax error. All we have handled is error reporting with

yyerror. Recall that by default yyparse returns after calling yyerror. This means that an erroneous input line causes the calculator program to exit. Now we show how to rectify this deficiency.

The Bison language itself includes the reserved word error, which may be included in the grammar rules. In the example below it has been added to one of the alternatives for line:

line:

’\n’

| exp ’\n’ { printf ("\t.10g\n", $1); }

| error ’\n’ { yyerrok; }

;

This addition to the grammar allows for simple error recovery in the event of a syntax error. If an expression that cannot be evaluated is read, the error will be recognized by the third rule for line, and parsing will continue. (The yyerror function is still called upon to print its message as well.) The action executes the statement yyerrok, a macro defined automatically by Bison; its meaning is that error recovery is complete (see [Chapter 6 [Error](#_bookmark170) [Recovery], page 127](#_bookmark170)). Note the difference between yyerrok and yyerror; neither one is a misprint.

This form of error recovery deals with syntax errors. There are other kinds of errors; for example, division by zero, which raises an exception signal that is normally fatal. A real calculator program must handle this signal and use longjmp to return to main and resume parsing input lines; it would also have to discard the rest of the current line of input. We won’t discuss this issue further because it is not specific to Bison programs.

## Location Tracking Calculator: ltcalc

This example extends the infix notation calculator with location tracking. This feature will be used to improve the error messages. For the sake of clarity, this example is a simple integer calculator, since most of the work needed to use locations will be done in the lexical analyzer.

* + 1. **Declarations for** ltcalc

The C and Bison declarations for the location tracking calculator are the same as the declarations for the infix notation calculator.

/\* Location tracking calculator. \*/

{

#include <math.h> int yylex (void);

void yyerror (char const \*); }

/\* Bison declarations. \*/ define api.value.type {int} token NUM

left ’-’ ’+’

left ’\*’ ’/’ precedence NEG right ’^’

/\* The grammar follows. \*/



Note there are no declarations specific to locations. Defining a data type for storing lo- cations is not needed: we will use the type provided by default (see [Section 3.5.1 [Data](#_bookmark80) [Types of Locations], page 71](#_bookmark80)), which is a four member structure with the following integer fields: first\_line, first\_column, last\_line and last\_column. By conventions, and in accordance with the GNU Coding Standards and common practice, the line and column count both start at 1.

* + 1. **Grammar Rules for** ltcalc

Whether handling locations or not has no effect on the syntax of your language. Therefore, grammar rules for this example will be very close to those of the previous example: we will only modify them to benefit from the new information.

Here, we will use locations to report divisions by zero, and locate the wrong expressions or subexpressions.

input:

empty

| input line

;

line:

’\n’

| exp ’\n’ { printf ("d\n", $1); }

;

exp:

NUM { $$ = $1; }

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | exp | ’+’ | exp | { | $$ | = | $1 | + | $3; | } |
| | | exp | ’-’ | exp | { | $$ | = | $1 | - | $3; | } |
| | | exp | ’\*’ | exp | { | $$ | = | $1 | \* | $3; | } |
| | | exp | ’/’ | exp |  |  |  |  |  |  |  |
|  | { |  |  |  |  |  |  |  |  |  |

if ($3)

$$ = $1 / $3; else

{

$$ = 1;

fprintf (stderr, "d. d- d. d: division by zero", @3.first\_line, @3.first\_column, @3.last\_line, @3.last\_column);

}

}

| ’-’ exp prec NEG { $$ = -$2; }

| exp ’^’ exp { $$ = pow ($1, $3); }

| ’(’ exp ’)’ { $$ = $2; }

This code shows how to reach locations inside of semantic actions, by using the pseudo- variables @*n* for rule components, and the pseudo-variable @$ for groupings.

We don’t need to assign a value to @$: the output parser does it automatically. By default, before executing the C code of each action, @$ is set to range from the beginning of @1 to the end of @*n*, for a rule with *n* components. This behavior can be redefined (see [Section 3.5.3 [Default Action for Locations], page 73](#_bookmark83)), and for very specific rules, @$ can be computed by hand.

* + 1. **The** ltcalc **Lexical Analyzer.**

Until now, we relied on Bison’s defaults to enable location tracking. The next step is to rewrite the lexical analyzer, and make it able to feed the parser with the token locations, as it already does for semantic values.

To this end, we must take into account every single character of the input text, to avoid the computed locations of being fuzzy or wrong:

int

yylex (void)

{

int c;

/\* Skip white space. \*/

while ((c = getchar ()) == ’ ’ || c == ’\t’)

++yylloc.last\_column;

/\* Step. \*/

yylloc.first\_line = yylloc.last\_line; yylloc.first\_column = yylloc.last\_column;

/\* Process numbers. \*/ if (isdigit (c))

{

yylval = c - ’0’;

++yylloc.last\_column;

while (isdigit (c = getchar ()))

{

++yylloc.last\_column;

yylval = yylval \* 10 + c - ’0’;

}

ungetc (c, stdin); return NUM;

}

/\* Return end-of-input. \*/ if (c == EOF)

return 0;

/\* Return a single char, and update location. \*/ if (c == ’\n’)

{

++yylloc.last\_line; yylloc.last\_column = 0;

}

else

++yylloc.last\_column; return c;

}

Basically, the lexical analyzer performs the same processing as before: it skips blanks and tabs, and reads numbers or single-character tokens. In addition, it updates yylloc, the global variable (of type YYLTYPE) containing the token’s location.

Now, each time this function returns a token, the parser has its number as well as its semantic value, and its location in the text. The last needed change is to initialize yylloc, for example in the controlling function:

int

main (void)

{

yylloc.first\_line = yylloc.last\_line = 1; yylloc.first\_column = yylloc.last\_column = 0; return yyparse ();

}

Remember that computing locations is not a matter of syntax. Every character must be associated to a location update, whether it is in valid input, in comments, in literal strings, and so on.

## Multi-Function Calculator: mfcalc

Now that the basics of Bison have been discussed, it is time to move on to a more advanced problem. The above calculators provided only five functions, ‘+’, ‘-’, ‘\*’, ‘/’ and ‘^’. It would be nice to have a calculator that provides other mathematical functions such as sin, cos, etc.

It is easy to add new operators to the infix calculator as long as they are only single- character literals. The lexical analyzer yylex passes back all nonnumeric characters as tokens, so new grammar rules suffice for adding a new operator. But we want something more flexible: built-in functions whose syntax has this form:

*function\_name* (*argument*)

At the same time, we will add memory to the calculator, by allowing you to create named variables, store values in them, and use them later. Here is a sample session with the multi-function calculator:

$ *mfcalc*

*pi = 3.141592653589*

*⇒* 3.1415926536

*sin(pi)*

*⇒* 0.0000000000

*alpha = beta1 = 2.3*

*⇒* 2.3000000000

*alpha*

*⇒* 2.3000000000

*ln(alpha)*

*⇒* 0.8329091229

*exp(ln(beta1))*

*⇒* 2.3000000000

$

Note that multiple assignment and nested function calls are permitted.

* + 1. **Declarations for** mfcalc

Here are the C and Bison declarations for the multi-function calculator.

{

#include <stdio.h> /\* For printf, etc. \*/

#include <math.h> /\* For pow, used in the grammar. \*/ #include "calc.h" /\* Contains definition of ’symrec’. \*/ int yylex (void);

void yyerror (char const \*); }

define api.value.type union /\* Generate YYSTYPE from these types: \*/ token <double> NUM /\* Simple double precision number. \*/ token <symrec\*> VAR FNCT /\* Symbol table pointer: variable and func- tion. \*/

type <double> exp

precedence ’=’ left ’-’ ’+’

left ’\*’ ’/’

precedence NEG /\* negation--unary minus \*/ right ’^’ /\* exponentiation \*/

The above grammar introduces only two new features of the Bison language. These features allow semantic values to have various data types (see [Section 3.4.2 [More Than](#_bookmark63) [One Value Type], page 62](#_bookmark63)).

The special union value assigned to the define variable api.value.type specifies that the symbols are defined with their data types. Bison will generate an appropriate definition of YYSTYPE to store these values.

Since values can now have various types, it is necessary to associate a type with each grammar symbol whose semantic value is used. These symbols are NUM, VAR, FNCT, and exp. Their declarations are augmented with their data type (placed between angle brackets). For instance, values of NUM are stored in double.

The Bison construct type is used for declaring nonterminal symbols, just as token is used for declaring token types. Previously we did not use type before because nonterminal

symbols are normally declared implicitly by the rules that define them. But exp must be declared explicitly so we can specify its value type. See [Section 3.7.4 [Nonterminal Symbols],](#_bookmark93) [page 77](#_bookmark93).

* + 1. **Grammar Rules for** mfcalc

Here are the grammar rules for the multi-function calculator. Most of them are copied directly from calc; three rules, those which mention VAR or FNCT, are new.

/\* The grammar follows. \*/ input:



empty

| input line

;

line:

’\n’

| exp ’\n’ { printf (".10g\n", $1); }

| error ’\n’ { yyerrok; }

;

exp:

NUM { $$ = $1; }

| VAR { $$ = $1->value.var; }

| VAR ’=’ exp { $$ = $3; $1->value.var = $3; }

| FNCT ’(’ exp ’)’ { $$ = (\*($1->value.fnctptr))($3); }

| exp ’+’ exp { $$ = $1 + $3; }

| exp ’-’ exp { $$ = $1 - $3; }

| exp ’\*’ exp { $$ = $1 \* $3; }

| exp ’/’ exp { $$ = $1 / $3; }

| ’-’ exp prec NEG { $$ = -$2; }

| exp ’^’ exp { $$ = pow ($1, $3); }

| ’(’ exp ’)’ { $$ = $2; }

;

/\* End of grammar. \*/



* + 1. **The** mfcalc **Symbol Table**

The multi-function calculator requires a symbol table to keep track of the names and mean- ings of variables and functions. This doesn’t affect the grammar rules (except for the actions) or the Bison declarations, but it requires some additional C functions for support.

The symbol table itself consists of a linked list of records. Its definition, which is kept in the header calc.h, is as follows. It provides for either functions or variables to be placed in the table.

/\* Function type. \*/

typedef double (\*func\_t) (double);

/\* Data type for links in the chain of symbols. \*/ struct symrec

{

char \*name; /\* name of symbol \*/

int type; /\* type of symbol: either VAR or FNCT \*/ union

{

double var; /\* value of a VAR \*/ func\_t fnctptr; /\* value of a FNCT \*/

} value;

struct symrec \*next; /\* link field \*/

};

typedef struct symrec symrec;

/\* The symbol table: a chain of ’struct symrec’. \*/ extern symrec \*sym\_table;

symrec \*putsym (char const \*, int); symrec \*getsym (char const \*);

The new version of main will call init\_table to initialize the symbol table:

struct init

{

char const \*fname; double (\*fnct) (double);

};

struct init const arith\_fncts[] =

{

{ "atan", atan },

{ "cos", cos },

{ "exp", exp },

{ "ln", log },

{ "sin", sin },

{ "sqrt", sqrt },

{ 0, 0 },

};

/\* The symbol table: a chain of ’struct symrec’. \*/ symrec \*sym\_table;

/\* Put arithmetic functions in table. \*/ static

void

init\_table (void)

{

int i;

for (i = 0; arith\_fncts[i].fname != 0; i++)

{

symrec \*ptr = putsym (arith\_fncts[i].fname, FNCT); ptr->value.fnctptr = arith\_fncts[i].fnct;

}

}

By simply editing the initialization list and adding the necessary include files, you can add additional functions to the calculator.

Two important functions allow look-up and installation of symbols in the symbol table. The function putsym is passed a name and the type (VAR or FNCT) of the object to be installed. The object is linked to the front of the list, and a pointer to the object is returned. The function getsym is passed the name of the symbol to look up. If found, a pointer to that symbol is returned; otherwise zero is returned.

#include <stdlib.h> /\* malloc. \*/ #include <string.h> /\* strlen. \*/

symrec \*

putsym (char const \*sym\_name, int sym\_type)

{

symrec \*ptr = (symrec \*) malloc (sizeof (symrec)); ptr->name = (char \*) malloc (strlen (sym\_name) + 1); strcpy (ptr->name,sym\_name);

ptr->type = sym\_type;

ptr->value.var = 0; /\* Set value to 0 even if fctn. \*/ ptr->next = (struct symrec \*)sym\_table;

sym\_table = ptr; return ptr;

}

symrec \*

getsym (char const \*sym\_name)

{

symrec \*ptr;

for (ptr = sym\_table; ptr != (symrec \*) 0; ptr = (symrec \*)ptr->next)

if (strcmp (ptr->name, sym\_name) == 0) return ptr;

return 0;

}

* + 1. **The** mfcalc **Lexer**

The function yylex must now recognize variables, numeric values, and the single-character arithmetic operators. Strings of alphanumeric characters with a leading letter are recognized as either variables or functions depending on what the symbol table says about them.

The string is passed to getsym for look up in the symbol table. If the name appears in the table, a pointer to its location and its type (VAR or FNCT) is returned to yyparse. If it is not already in the table, then it is installed as a VAR using putsym. Again, a pointer and its type (which must be VAR) is returned to yyparse.

No change is needed in the handling of numeric values and arithmetic operators in yylex. #include <ctype.h>

int

yylex (void)

{

int c;

/\* Ignore white space, get first nonwhite character. \*/ while ((c = getchar ()) == ’ ’ || c == ’\t’)

continue;

if (c == EOF) return 0;

/\* Char starts a number => parse the number. \*/ if (c == ’.’ || isdigit (c))

{

ungetc (c, stdin);

scanf ("lf", &yylval.NUM); return NUM;

}

Bison generated a definition of YYSTYPE with a member named NUM to store value of NUM

symbols.

/\* Char starts an identifier => read the name. \*/ if (isalpha (c))

{

/\* Initially make the buffer long enough for a 40-character symbol name. \*/

static size\_t length = 40; static char \*symbuf = 0; symrec \*s;

int i;

if (!symbuf)

symbuf = (char \*) malloc (length + 1); i = 0;

do

{

/\* If buffer is full, make it bigger. \*/ if (i == length)

{

length \*= 2;

symbuf = (char \*) realloc (symbuf, length + 1);

}

/\* Add this character to the buffer. \*/ symbuf[i++] = c;

/\* Get another character. \*/ c = getchar ();

}

while (isalnum (c));

ungetc (c, stdin); symbuf[i] = ’\0’;

s = getsym (symbuf); if (s == 0)

s = putsym (symbuf, VAR);

\*((symrec\*\*) &yylval) = s; return s->type;

}

/\* Any other character is a token by itself. \*/ return c;

}

* + 1. **The** mfcalc **Main**

The error reporting function is unchanged, and the new version of main includes a call to init\_table and sets the yydebug on user demand (See [Section 8.4 [Tracing Your Parser],](#_bookmark188) [page 143](#_bookmark188), for details):

/\* Called by yyparse on error. \*/ void

yyerror (char const \*s)

{

fprintf (stderr, "s\n", s);

}

int

main (int argc, char const\* argv[])

{

int i;

/\* Enable parse traces on option -p. \*/ for (i = 1; i < argc; ++i)

if (!strcmp(argv[i], "-p")) yydebug = 1;

init\_table (); return yyparse ();

}

This program is both powerful and flexible. You may easily add new functions, and it is a simple job to modify this code to install predefined variables such as pi or e as well.

## Exercises

1. Add some new functions from math.h to the initialization list.
2. Add another array that contains constants and their values. Then modify init\_table to add these constants to the symbol table. It will be easiest to give the constants type VAR.
3. Make the program report an error if the user refers to an uninitialized variable in any way except to store a value in it.

# Bison Grammar Files

Bison takes as input a context-free grammar specification and produces a C-language func- tion that recognizes correct instances of the grammar.

The Bison grammar file conventionally has a name ending in ‘.y’. See [Chapter 9 [In-](#_bookmark194) [voking Bison], page 149](#_bookmark194).

## Outline of a Bison Grammar

A Bison grammar file has four main sections, shown here with the appropriate delimiters:

{

*Prologue*

}

*Bison declarations*



*Grammar rules*



*Epilogue*

Comments enclosed in ‘/\* ... \*/’ may appear in any of the sections. As a GNU exten- sion, ‘//’ introduces a comment that continues until end of line.

#### The prologue

The *Prologue* section contains macro definitions and declarations of functions and variables that are used in the actions in the grammar rules. These are copied to the beginning of the parser implementation file so that they precede the definition of yyparse. You can use ‘#include’ to get the declarations from a header file. If you don’t need any C declarations, you may omit the ‘{’ and ‘}’ delimiters that bracket this section.

The *Prologue* section is terminated by the first occurrence of ‘}’ that is outside a comment, a string literal, or a character constant.

You may have more than one *Prologue* section, intermixed with the *Bison declarations*. This allows you to have C and Bison declarations that refer to each other. For example, the union declaration may use types defined in a header file, and you may wish to prototype functions that take arguments of type YYSTYPE. This can be done with two *Prologue* blocks, one before and one after the union declaration.

{

#define \_GNU\_SOURCE #include <stdio.h> #include "ptypes.h"

}

union { long n;

tree t; /\* tree is defined in ptypes.h. \*/

}

{

static void print\_token\_value (FILE \*, int, YYSTYPE); #define YYPRINT(F, N, L) print\_token\_value (F, N, L)

}

...

When in doubt, it is usually safer to put prologue code before all Bison declarations, rather than after. For example, any definitions of feature test macros like \_GNU\_SOURCE or

\_POSIX\_C\_SOURCE should appear before all Bison declarations, as feature test macros can affect the behavior of Bison-generated #include directives.

#### Prologue Alternatives

The functionality of *Prologue* sections can often be subtle and inflexible. As an alternative, Bison provides a code directive with an explicit qualifier field, which identifies the purpose of the code and thus the location(s) where Bison should generate it. For C/C++, the qualifier can be omitted for the default location, or it can be one of requires, provides, top. See [Section 3.7.14 [%code Summary], page 92](#_bookmark115).

Look again at the example of the previous section:

{

#define \_GNU\_SOURCE #include <stdio.h> #include "ptypes.h"

}

union { long n;

tree t; /\* tree is defined in ptypes.h. \*/

}

{

static void print\_token\_value (FILE \*, int, YYSTYPE); #define YYPRINT(F, N, L) print\_token\_value (F, N, L)

}

...

Notice that there are two *Prologue* sections here, but there’s a subtle distinction between their functionality. For example, if you decide to override Bison’s default definition for YYLTYPE, in which *Prologue* section should you write your new definition? You should write it in the first since Bison will insert that code into the parser implementation file *before* the default YYLTYPE definition. In which *Prologue* section should you prototype an internal function, trace\_token, that accepts YYLTYPE and yytokentype as arguments? You should prototype it in the second since Bison will insert that code *after* the YYLTYPE and yytokentype definitions.

This distinction in functionality between the two *Prologue* sections is established by the appearance of the union between them. This behavior raises a few questions. First, why

should the position of a union affect definitions related to YYLTYPE and yytokentype? Second, what if there is no union? In that case, the second kind of *Prologue* section is not available. This behavior is not intuitive.

To avoid this subtle union dependency, rewrite the example using a code top and an unqualified code. Let’s go ahead and add the new YYLTYPE definition and the trace\_token prototype at the same time:

code top {

#define \_GNU\_SOURCE #include <stdio.h>

/\* WARNING: The following code really belongs

\* in a ’code requires’; see below. \*/

#include "ptypes.h" #define YYLTYPE YYLTYPE

typedef struct YYLTYPE

{

int first\_line; int first\_column; int last\_line; int last\_column; char \*filename;

} YYLTYPE;

}

union { long n;

tree t; /\* tree is defined in ptypes.h. \*/

}

code {

static void print\_token\_value (FILE \*, int, YYSTYPE); #define YYPRINT(F, N, L) print\_token\_value (F, N, L)

static void trace\_token (enum yytokentype token, YYLTYPE loc);

}

...

In this way, code top and the unqualified code achieve the same functionality as the two kinds of *Prologue* sections, but it’s always explicit which kind you intend. Moreover, both kinds are always available even in the absence of union.

The code top block above logically contains two parts. The first two lines before the warning need to appear near the top of the parser implementation file. The first line after the warning is required by YYSTYPE and thus also needs to appear in the parser implementation file. However, if you’ve instructed Bison to generate a parser header file (see [Section 3.7.12](#_bookmark105) [[%defines], page 83](#_bookmark105)), you probably want that line to appear before the YYSTYPE definition

in that header file as well. The YYLTYPE definition should also appear in the parser header file to override the default YYLTYPE definition there.

In other words, in the code top block above, all but the first two lines are dependency code required by the YYSTYPE and YYLTYPE definitions. Thus, they belong in one or more code requires:

code top {

#define \_GNU\_SOURCE #include <stdio.h>

}

code requires { #include "ptypes.h"

}

union { long n;

tree t; /\* tree is defined in ptypes.h. \*/

}

code requires {

#define YYLTYPE YYLTYPE

typedef struct YYLTYPE

{

int first\_line; int first\_column; int last\_line; int last\_column; char \*filename;

} YYLTYPE;

}

code {

static void print\_token\_value (FILE \*, int, YYSTYPE); #define YYPRINT(F, N, L) print\_token\_value (F, N, L)

static void trace\_token (enum yytokentype token, YYLTYPE loc);

}

...

Now Bison will insert #include "ptypes.h" and the new YYLTYPE definition before the Bison-generated YYSTYPE and YYLTYPE definitions in both the parser implementation file and the parser header file. (By the same reasoning, code requires would also be the appropriate place to write your own definition for YYSTYPE.)

When you are writing dependency code for YYSTYPE and YYLTYPE, you should prefer code requires over code top regardless of whether you instruct Bison to generate a parser header file. When you are writing code that you need Bison to insert only into the parser implementation file and that has no special need to appear at the top of that file, you should prefer the unqualified code over code top. These practices will make the purpose

of each block of your code explicit to Bison and to other developers reading your grammar file. Following these practices, we expect the unqualified code and code requires to be the most important of the four *Prologue* alternatives.

At some point while developing your parser, you might decide to provide trace\_token to modules that are external to your parser. Thus, you might wish for Bison to insert the prototype into both the parser header file and the parser implementation file. Since this function is not a dependency required by YYSTYPE or YYLTYPE, it doesn’t make sense to move its prototype to a code requires. More importantly, since it depends upon YYLTYPE and yytokentype, code requires is not sufficient. Instead, move its prototype from the unqualified code to a code provides:

code top {

#define \_GNU\_SOURCE #include <stdio.h>

}

code requires { #include "ptypes.h"

}

union { long n;

tree t; /\* tree is defined in ptypes.h. \*/

}

code requires {

#define YYLTYPE YYLTYPE

typedef struct YYLTYPE

{

int first\_line; int first\_column; int last\_line; int last\_column; char \*filename;

} YYLTYPE;

}

code provides {

void trace\_token (enum yytokentype token, YYLTYPE loc);

}

code {

static void print\_token\_value (FILE \*, int, YYSTYPE); #define YYPRINT(F, N, L) print\_token\_value (F, N, L)

}

...

Bison will insert the trace\_token prototype into both the parser header file and the parser implementation file after the definitions for yytokentype, YYLTYPE, and YYSTYPE.

The above examples are careful to write directives in an order that reflects the layout of the generated parser implementation and header files: code top, code requires, code provides, and then code. While your grammar files may generally be easier to read if you also follow this order, Bison does not require it. Instead, Bison lets you choose an organization that makes sense to you.

You may declare any of these directives multiple times in the grammar file. In that case, Bison concatenates the contained code in declaration order. This is the only way in which the position of one of these directives within the grammar file affects its functionality.

The result of the previous two properties is greater flexibility in how you may organize your grammar file. For example, you may organize semantic-type-related directives by semantic type:

code requires { #include "type1.h" } union { type1 field1; }

destructor { type1\_free ($$); } <field1> printer { type1\_print (yyoutput, $$); } <field1>

code requires { #include "type2.h" } union { type2 field2; }

destructor { type2\_free ($$); } <field2> printer { type2\_print (yyoutput, $$); } <field2>

You could even place each of the above directive groups in the rules section of the grammar file next to the set of rules that uses the associated semantic type. (In the rules section, you must terminate each of those directives with a semicolon.) And you don’t have to worry that some directive (like a union) in the definitions section is going to adversely affect their functionality in some counter-intuitive manner just because it comes first. Such an organization is not possible using *Prologue* sections.

This section has been concerned with explaining the advantages of the four *Prologue* alternatives over the original Yacc *Prologue*. However, in most cases when using these directives, you shouldn’t need to think about all the low-level ordering issues discussed here. Instead, you should simply use these directives to label each block of your code according to its purpose and let Bison handle the ordering. code is the most generic label. Move code to code requires, code provides, or code top as needed.

#### The Bison Declarations Section

The *Bison declarations* section contains declarations that define terminal and nonterminal symbols, specify precedence, and so on. In some simple grammars you may not need any declarations. See [Section 3.7 [Bison Declarations], page 75](#_bookmark87).

#### The Grammar Rules Section

The *grammar rules* section contains one or more Bison grammar rules, and nothing else. See [Section 3.3 [Syntax of Grammar Rules], page 59](#_bookmark55).

There must always be at least one grammar rule, and the first ‘ ’ (which precedes the grammar rules) may never be omitted even if it is the first thing in the file.



#### The epilogue

The *Epilogue* is copied verbatim to the end of the parser implementation file, just as the *Prologue* is copied to the beginning. This is the most convenient place to put anything that you want to have in the parser implementation file but which need not come before the definition of yyparse. For example, the definitions of yylex and yyerror often go here. Because C requires functions to be declared before being used, you often need to declare functions like yylex and yyerror in the Prologue, even if you define them in the Epilogue. See [Chapter 4 [Parser C-Language Interface], page 97](#_bookmark119).

If the last section is empty, you may omit the ‘ ’ that separates it from the grammar rules.



The Bison parser itself contains many macros and identifiers whose names start with ‘yy’ or ‘YY’, so it is a good idea to avoid using any such names (except those documented in this manual) in the epilogue of the grammar file.

## Symbols, Terminal and Nonterminal

*Symbols* in Bison grammars represent the grammatical classifications of the language.

A *terminal symbol* (also known as a *token type*) represents a class of syntactically equivalent tokens. You use the symbol in grammar rules to mean that a token in that class is allowed. The symbol is represented in the Bison parser by a numeric code, and the yylex function returns a token type code to indicate what kind of token has been read. You don’t need to know what the code value is; you can use the symbol to stand for it.

A *nonterminal symbol* stands for a class of syntactically equivalent groupings. The symbol name is used in writing grammar rules. By convention, it should be all lower case. Symbol names can contain letters, underscores, periods, and non-initial digits and

dashes. Dashes in symbol names are a GNU extension, incompatible with POSIX Yacc. Periods and dashes make symbol names less convenient to use with named references, which require brackets around such names (see [Section 3.6 [Named References], page 74](#_bookmark85)). Terminal symbols that contain periods or dashes make little sense: since they are not valid symbols (in most programming languages) they are not exported as token names.

There are three ways of writing terminal symbols in the grammar:

A *named token type* is written with an identifier, like an identifier in C. By convention, it should be all upper case. Each such name must be defined with a Bison declaration such as token. See [Section 3.7.2 [Token Type Names], page 75](#_bookmark89).

*•*

A *character token type* (or *literal character token*) is written in the grammar using the same syntax used in C for character constants; for example, ’+’ is a character token type. A character token type doesn’t need to be declared unless you need to specify its semantic value data type (see [Section 3.4.1 [Data Types of Semantic Values], page 61](#_bookmark61)), associativity, or precedence (see [Section 5.3 [Operator Precedence], page 109](#_bookmark145)).

*•*

By convention, a character token type is used only to represent a token that consists of that particular character. Thus, the token type ’+’ is used to represent the character ‘+’ as a token. Nothing enforces this convention, but if you depart from it, your program will confuse other readers.

All the usual escape sequences used in character literals in C can be used in Bison as well, but you must not use the null character as a character literal because its

numeric code, zero, signifies end-of-input (see [Section 4.6.1 [Calling Convention for](#_bookmark127) [yylex], page 99](#_bookmark127)). Also, unlike standard C, trigraphs have no special meaning in Bison character literals, nor is backslash-newline allowed.

A *literal string token* is written like a C string constant; for example, "<=" is a literal string token. A literal string token doesn’t need to be declared unless you need to specify its semantic value data type (see [Section 3.4.1 [Value Type], page 61](#_bookmark61)), associativity, or precedence (see [Section 5.3 [Precedence], page 109](#_bookmark145)).

*•*

You can associate the literal string token with a symbolic name as an alias, using the token declaration (see [Section 3.7.2 [Token Declarations], page 75](#_bookmark89)). If you don’t do that, the lexical analyzer has to retrieve the token number for the literal string token from the yytname table (see [Section 4.6.1 [Calling Convention], page 99](#_bookmark127)).

**Warning**: literal string tokens do not work in Yacc.

By convention, a literal string token is used only to represent a token that consists of that particular string. Thus, you should use the token type "<=" to represent the string ‘<=’ as a token. Bison does not enforce this convention, but if you depart from it, people who read your program will be confused.

All the escape sequences used in string literals in C can be used in Bison as well, except that you must not use a null character within a string literal. Also, unlike Standard C, trigraphs have no special meaning in Bison string literals, nor is backslash- newline allowed. A literal string token must contain two or more characters; for a token containing just one character, use a character token (see above).

How you choose to write a terminal symbol has no effect on its grammatical meaning. That depends only on where it appears in rules and on when the parser function returns that symbol.

The value returned by yylex is always one of the terminal symbols, except that a zero or negative value signifies end-of-input. Whichever way you write the token type in the grammar rules, you write it the same way in the definition of yylex. The numeric code for a character token type is simply the positive numeric code of the character, so yylex can use the identical value to generate the requisite code, though you may need to convert it to unsigned char to avoid sign-extension on hosts where char is signed. Each named token type becomes a C macro in the parser implementation file, so yylex can use the name to stand for the code. (This is why periods don’t make sense in terminal symbols.) See [Section 4.6.1 [Calling Convention for yylex], page 99](#_bookmark127).

If yylex is defined in a separate file, you need to arrange for the token-type macro definitions to be available there. Use the ‘-d’ option when you run Bison, so that it will write these macro definitions into a separate header file *name*.tab.h which you can include in the other source files that need it. See [Chapter 9 [Invoking Bison], page 149](#_bookmark194).

If you want to write a grammar that is portable to any Standard C host, you must use only nonnull character tokens taken from the basic execution character set of Standard C. This set consists of the ten digits, the 52 lower- and upper-case English letters, and the characters in the following C-language string:

"\a\b\t\n\v\f\r !\"#&’()\*+,-./:;<=>?[\\]^\_{|}~"

The yylex function and Bison must use a consistent character set and encoding for char- acter tokens. For example, if you run Bison in an ASCII environment, but then compile

and run the resulting program in an environment that uses an incompatible character set like EBCDIC, the resulting program may not work because the tables generated by Bison will assume ASCII numeric values for character tokens. It is standard practice for software distributions to contain C source files that were generated by Bison in an ASCII environ- ment, so installers on platforms that are incompatible with ASCII must rebuild those files before compiling them.

The symbol error is a terminal symbol reserved for error recovery (see [Chapter 6 [Error](#_bookmark170) [Recovery], page 127](#_bookmark170)); you shouldn’t use it for any other purpose. In particular, yylex should never return this value. The default value of the error token is 256, unless you explicitly assigned 256 to one of your tokens with a token declaration.

## Grammar Rules

A Bison grammar is a list of rules.

#### Syntax of Grammar Rules

A Bison grammar rule has the following general form:

*result*: *components*...;

where *result* is the nonterminal symbol that this rule describes, and *components* are var- ious terminal and nonterminal symbols that are put together by this rule (see [Section 3.2](#_bookmark52) [[Symbols], page 57](#_bookmark52)).

For example,

exp: exp ’+’ exp;

says that two groupings of type exp, with a ‘+’ token in between, can be combined into a larger grouping of type exp.

White space in rules is significant only to separate symbols. You can add extra white space as you wish.

Scattered among the components can be *actions* that determine the semantics of the rule. An action looks like this:

{*C statements*}

This is an example of *braced code*, that is, C code surrounded by braces, much like a compound statement in C. Braced code can contain any sequence of C tokens, so long as its braces are balanced. Bison does not check the braced code for correctness directly; it merely copies the code to the parser implementation file, where the C compiler can check it.

Within braced code, the balanced-brace count is not affected by braces within comments, string literals, or character constants, but it is affected by the C digraphs ‘<’ and ‘>’ that represent braces. At the top level braced code must be terminated by ‘}’ and not by a digraph. Bison does not look for trigraphs, so if braced code uses trigraphs you should ensure that they do not affect the nesting of braces or the boundaries of comments, string literals, or character constants.

Usually there is only one action and it follows the components. See [Section 3.4.6 [Ac-](#_bookmark68) [tions], page 64](#_bookmark68).

Multiple rules for the same *result* can be written separately or can be joined with the vertical-bar character ‘|’ as follows:

*result*:

*rule1-components*...

| *rule2-components*...

...

;

They are still considered distinct rules even when joined in this way.

#### Empty Rules

A rule is said to be *empty* if its right-hand side (*components*) is empty. It means that *result*

can match the empty string. For example, here is how to define an optional semicolon:

semicolon.opt: | ";";

It is easy not to see an empty rule, especially when | is used. The empty directive allows to make explicit that a rule is empty on purpose:

semicolon.opt: empty

| ";"

;

Flagging a non-empty rule with empty is an error. If run with -Wempty-rule, bison will report empty rules without empty. Using empty enables this warning, unless -Wno- empty-rule was specified.

The empty directive is a Bison extension, it does not work with Yacc. To remain compatible with POSIX Yacc, it is customary to write a comment ‘/\* empty \*/’ in each rule with no components:

semicolon.opt:

/\* empty \*/

| ";"

;

#### Recursive Rules

A rule is called *recursive* when its *result* nonterminal appears also on its right hand side. Nearly all Bison grammars need to use recursion, because that is the only way to define a sequence of any number of a particular thing. Consider this recursive definition of a comma-separated sequence of one or more expressions:

expseq1: exp

| expseq1 ’,’ exp

;

Since the recursive use of expseq1 is the leftmost symbol in the right hand side, we call this *left recursion*. By contrast, here the same construct is defined using *right recursion*:

expseq1: exp

| exp ’,’ expseq1

;

Any kind of sequence can be defined using either left recursion or right recursion, but you should always use left recursion, because it can parse a sequence of any number of elements with bounded stack space. Right recursion uses up space on the Bison stack in proportion to the number of elements in the sequence, because all the elements must be shifted onto the stack before the rule can be applied even once. See [Chapter 5 [The Bison Parser Algorithm],](#_bookmark140) [page 107](#_bookmark140), for further explanation of this.

*Indirect* or *mutual* recursion occurs when the result of the rule does not appear directly on its right hand side, but does appear in rules for other nonterminals which do appear on its right hand side.

For example:

expr:

primary

| primary ’+’ primary

;

primary: constant

| ’(’ expr ’)’

;

defines two mutually-recursive nonterminals, since each refers to the other.

## Defining Language Semantics

The grammar rules for a language determine only the syntax. The semantics are determined by the semantic values associated with various tokens and groupings, and by the actions taken when various groupings are recognized.

For example, the calculator calculates properly because the value associated with each expression is the proper number; it adds properly because the action for the grouping ‘*x* + *y*’ is to add the numbers associated with *x* and *y*.

#### Data Types of Semantic Values

In a simple program it may be sufficient to use the same data type for the semantic values of all language constructs. This was true in the RPN and infix calculator examples (see [Section 2.1 [Reverse Polish Notation Calculator], page 31](#_bookmark22)).

Bison normally uses the type int for semantic values if your program uses the same data type for all language constructs. To specify some other type, define the define variable api.value.type like this:

define api.value.type {double}

or

define api.value.type {struct semantic\_type}

The value of api.value.type should be a type name that does not contain parentheses

or square brackets.

Alternatively, instead of relying of Bison’s define support, you may rely on the C/C++ preprocessor and define YYSTYPE as a macro, like this:

#define YYSTYPE double

This macro definition must go in the prologue of the grammar file (see [Section 3.1 [Outline](#_bookmark45) [of a Bison Grammar], page 51](#_bookmark45)). If compatibility with POSIX Yacc matters to you, use this. Note however that Bison cannot know YYSTYPE’s value, not even whether it is defined, so there are services it cannot provide. Besides this works only for languages that have a preprocessor.

#### More Than One Value Type

In most programs, you will need different data types for different kinds of tokens and groupings. For example, a numeric constant may need type int or long, while a string constant needs type char \*, and an identifier might need a pointer to an entry in the symbol table.

To use more than one data type for semantic values in one parser, Bison requires you to do two things:

* + - * Specify the entire collection of possible data types. There are several options:
        + let Bison compute the union type from the tags you assign to symbols;

use the union Bison declaration (see [Section 3.4.4 [The Union Declaration],](#_bookmark66) [page 63](#_bookmark66));

*•*

define the define variable api.value.type to be a union type whose members are the type tags (see [Section 3.4.5 [Providing a Structured Semantic Value Type],](#_bookmark67) [page 64](#_bookmark67));

*•*

use a typedef or a #define to define YYSTYPE to be a union type whose member names are the type tags.

*•*

Choose one of those types for each symbol (terminal or nonterminal) for which seman- tic values are used. This is done for tokens with the token Bison declaration (see [Section 3.7.2 [Token Type Names], page 75](#_bookmark89)) and for groupings with the type Bison declaration (see [Section 3.7.4 [Nonterminal Symbols], page 77](#_bookmark93)).

*•*

#### Generating the Semantic Value Type

The special value union of the define variable api.value.type instructs Bison that the tags used with the token and type directives are genuine types, not names of members of YYSTYPE.

For example:

define api.value.type union token <int> INT "integer" token <int> ’n’

type <int> expr

token <char const \*> ID "identifier"

generates an appropriate value of YYSTYPE to support each symbol type. The name of the member of YYSTYPE for tokens than have a declared identifier *id* (such as INT and ID above, but not ’n’) is *id*. The other symbols have unspecified names on which you should not depend; instead, relying on C casts to access the semantic value with the appropriate type:

/\* For an "integer". \*/ yylval.INT = 42;

return INT;

/\* For an ’n’, also declared as int. \*/

\*((int\*)&yylval) = 42; return ’n’;

/\* For an "identifier". \*/ yylval.ID = "42";

return ID;

If the define variable api.token.prefix is defined (see [Section 3.7.13](#_bookmark109) [[api.token.prefix], page 86](#_bookmark109)), then it is also used to prefix the union member names. For instance, with ‘define api.token.prefix {TOK\_}’:

/\* For an "integer". \*/ yylval.TOK\_INT = 42; return TOK\_INT;

This Bison extension cannot work if yacc (or -y/--yacc) is enabled, as POSIX man- dates that Yacc generate tokens as macros (e.g., ‘#define INT 258’, or ‘#define TOK\_INT 258’).

A similar feature is provided for C++ that in addition overcomes C++ limitations (that forbid non-trivial objects to be part of a union): ‘ define api.value.type variant’, see [Section 10.1.2.2 [C++ Variants], page 158](#_bookmark202).

#### The Union Declaration

The union declaration specifies the entire collection of possible data types for semantic values. The keyword union is followed by braced code containing the same thing that goes inside a union in C.

For example:

union { double val; symrec \*tptr;

}

This says that the two alternative types are double and symrec \*. They are given names val and tptr; these names are used in the token and type declarations to pick one of the types for a terminal or nonterminal symbol (see [Section 3.7.4 [Nonterminal Symbols],](#_bookmark93) [page 77](#_bookmark93)).

As an extension to POSIX, a tag is allowed after the union. For example:

union value { double val; symrec \*tptr;

}

specifies the union tag value, so the corresponding C type is union value. If you do not specify a tag, it defaults to YYSTYPE (see [Section 3.7.13 [api.value.union.name], page 86](#_bookmark109)).

As another extension to POSIX, you may specify multiple union declarations; their contents are concatenated. However, only the first union declaration can specify a tag.

Note that, unlike making a union declaration in C, you need not write a semicolon after the closing brace.

#### Providing a Structured Semantic Value Type

Instead of union, you can define and use your own union type YYSTYPE if your grammar contains at least one ‘<*type*>’ tag. For example, you can put the following into a header file parser.h:

union YYSTYPE { double val; symrec \*tptr;

};

and then your grammar can use the following instead of union: {

#include "parser.h"

}

define api.value.type {union YYSTYPE} type <val> expr

token <tptr> ID

Actually, you may also provide a struct rather that a union, which may be handy if you want to track information for every symbol (such as preceding comments).

The type you provide may even be structured and include pointers, in which case the type tags you provide may be composite, with ‘.’ and ‘->’ operators.

#### Actions

An action accompanies a syntactic rule and contains C code to be executed each time an instance of that rule is recognized. The task of most actions is to compute a semantic value for the grouping built by the rule from the semantic values associated with tokens or smaller groupings.

An action consists of braced code containing C statements, and can be placed at any position in the rule; it is executed at that position. Most rules have just one action at the end of the rule, following all the components. Actions in the middle of a rule are tricky and used only for special purposes (see [Section 3.4.8 [Actions in Mid-Rule], page 66](#_bookmark72)).

The C code in an action can refer to the semantic values of the components matched by the rule with the construct $*n*, which stands for the value of the *n*th component. The semantic value for the grouping being constructed is $$. In addition, the semantic values of symbols can be accessed with the named references construct $*name* or $[*name*]. Bison translates both of these constructs into expressions of the appropriate type when it copies the actions into the parser implementation file. $$ (or $*name*, when it stands for the current grouping) is translated to a modifiable lvalue, so it can be assigned to.

Here is a typical example:

exp:

...

| exp ’+’ exp { $$ = $1 + $3; }

Or, in terms of named references:

exp[result]:

...

| exp[left] ’+’ exp[right] { $result = $left + $right; }

This rule constructs an exp from two smaller exp groupings connected by a plus-sign token. In the action, $1 and $3 ($left and $right) refer to the semantic values of the two component exp groupings, which are the first and third symbols on the right hand side of the rule. The sum is stored into $$ ($result) so that it becomes the semantic value of the addition-expression just recognized by the rule. If there were a useful semantic value associated with the ‘+’ token, it could be referred to as $2.

See [Section 3.6 [Named References], page 74](#_bookmark85), for more information about using the named references construct.

Note that the vertical-bar character ‘|’ is really a rule separator, and actions are attached to a single rule. This is a difference with tools like Flex, for which ‘|’ stands for either “or”, or “the same action as that of the next rule”. In the following example, the action is triggered only when ‘b’ is found:

a-or-b: ’a’|’b’ { a\_or\_b\_found = 1; };

If you don’t specify an action for a rule, Bison supplies a default: $$ = $1. Thus, the value of the first symbol in the rule becomes the value of the whole rule. Of course, the default action is valid only if the two data types match. There is no meaningful default action for an empty rule; every empty rule must have an explicit action unless the rule’s value does not matter.

$*n* with *n* zero or negative is allowed for reference to tokens and groupings on the stack *before* those that match the current rule. This is a very risky practice, and to use it reliably you must be certain of the context in which the rule is applied. Here is a case in which you can use this reliably:

foo:

expr bar ’+’ expr { ... }

| expr bar ’-’ expr { ... }

;

bar:

empty { previous\_expr = $0; }

;

As long as bar is used only in the fashion shown here, $0 always refers to the expr which precedes bar in the definition of foo.

It is also possible to access the semantic value of the lookahead token, if any, from a semantic action. This semantic value is stored in yylval. See [Section 4.8 [Special Features](#_bookmark136) [for Use in Actions], page 103](#_bookmark136).

#### Data Types of Values in Actions

If you have chosen a single data type for semantic values, the $$ and $*n* constructs always have that data type.

If you have used union to specify a variety of data types, then you must declare a choice among these types for each terminal or nonterminal symbol that can have a semantic value. Then each time you use $$ or $*n*, its data type is determined by which symbol it refers to in the rule. In this example,

exp:

...

| exp ’+’ exp { $$ = $1 + $3; }

$1 and $3 refer to instances of exp, so they all have the data type declared for the nonter- minal symbol exp. If $2 were used, it would have the data type declared for the terminal symbol ’+’, whatever that might be.

Alternatively, you can specify the data type when you refer to the value, by inserting ‘<*type*>’ after the ‘$’ at the beginning of the reference. For example, if you have defined types as shown here:

union { int itype;

double dtype;

}

then you can write $<itype>1 to refer to the first subunit of the rule as an integer, or

$<dtype>1 to refer to it as a double.

#### Actions in Mid-Rule

Occasionally it is useful to put an action in the middle of a rule. These actions are written just like usual end-of-rule actions, but they are executed before the parser even recognizes the following components.

#### Using Mid-Rule Actions

A mid-rule action may refer to the components preceding it using $*n*, but it may not refer to subsequent components because it is run before they are parsed.

The mid-rule action itself counts as one of the components of the rule. This makes a difference when there is another action later in the same rule (and usually there is another at the end): you have to count the actions along with the symbols when working out which number *n* to use in $*n*.

The mid-rule action can also have a semantic value. The action can set its value with an assignment to $$, and actions later in the rule can refer to the value using $*n*. Since there is no symbol to name the action, there is no way to declare a data type for the value in advance, so you must use the ‘$<...>*n*’ construct to specify a data type each time you refer to this value.

There is no way to set the value of the entire rule with a mid-rule action, because assignments to $$ do not have that effect. The only way to set the value for the entire rule is with an ordinary action at the end of the rule.

Here is an example from a hypothetical compiler, handling a let statement that looks like ‘let (*variable*) *statement*’ and serves to create a variable named *variable* temporarily for the duration of *statement*. To parse this construct, we must put *variable* into the symbol table while *statement* is parsed, then remove it afterward. Here is how it is done:

stmt:

"let" ’(’ var ’)’

{

$<context>$ = push\_context (); declare\_variable ($3);

}

stmt

{

$$ = $6;

pop\_context ($<context>5);

}

As soon as ‘let (*variable*)’ has been recognized, the first action is run. It saves a copy of the current semantic context (the list of accessible variables) as its semantic value, using alternative context in the data-type union. Then it calls declare\_variable to add the new variable to that list. Once the first action is finished, the embedded statement stmt can be parsed.

Note that the mid-rule action is component number 5, so the ‘stmt’ is component num- ber 6. Named references can be used to improve the readability and maintainability (see [Section 3.6 [Named References], page 74](#_bookmark85)):

stmt:

"let" ’(’ var ’)’

{

$<context>let = push\_context (); declare\_variable ($3);

}[let] stmt

{

$$ = $6;

pop\_context ($<context>let);

}

After the embedded statement is parsed, its semantic value becomes the value of the entire let-statement. Then the semantic value from the earlier action is used to restore the prior list of variables. This removes the temporary let-variable from the list so that it won’t appear to exist while the rest of the program is parsed.

Because the types of the semantic values of mid-rule actions are unknown to Bison, type- based features (e.g., ‘printer’, ‘destructor’) do not work, which could result in memory leaks. They also forbid the use of the variant implementation of the api.value.type in C++ (see [Section 10.1.2.2 [C++ Variants], page 158](#_bookmark202)).

See [Section 3.4.8.2 [Typed Mid-Rule Actions], page 67](#_bookmark74), for one way to address this issue, and [Section 3.4.8.3 [Mid-Rule Action Translation], page 68](#_bookmark76), for another: turning mid-action actions into regular actions.

#### Typed Mid-Rule Actions

In the above example, if the parser initiates error recovery (see [Chapter 6 [Error Recovery],](#_bookmark170) [page 127](#_bookmark170)) while parsing the tokens in the embedded statement stmt, it might discard the

previous semantic context $<context>5 without restoring it. Thus, $<context>5 needs a destructor (see [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95)), and Bison needs the type of the semantic value (context) to select the right destructor.

As an extension to Yacc’s mid-rule actions, Bison offers a means to type their semantic value: specify its type tag (‘<...>’ before the mid-rule action.

Consider the previous example, with an untyped mid-rule action:

stmt:

"let" ’(’ var ’)’

{

$<context>$ = push\_context (); // \*\*\* declare\_variable ($3);

}

stmt

{

$$ = $6;

pop\_context ($<context>5); // \*\*\*

}

If instead you write:

stmt:

"let" ’(’ var ’)’

<context>{ // \*\*\*

$$ = push\_context (); // \*\*\* declare\_variable ($3);

}

stmt

{

$$ = $6;

pop\_context ($5); // \*\*\*

}

then printer and destructor work properly (no more leaks!), C++ variants can be used, and redundancy is reduced (<context> is specified once).

#### Mid-Rule Action Translation

Mid-rule actions are actually transformed into regular rules and actions. The various reports generated by Bison (textual, graphical, etc., see [Section 8.1 [Understanding Your Parser],](#_bookmark178) [page 133](#_bookmark178)) reveal this translation, best explained by means of an example. The following rule:

exp: { a(); } "b" { c(); } { d(); } "e" { f(); };

is translated into:

$@1: empty { a(); };

$@2: empty { c(); };

$@3: empty { d(); };

exp: $@1 "b" $@2 $@3 "e" { f(); };

with new nonterminal symbols $@*n*, where *n* is a number.

A mid-rule action is expected to generate a value if it uses $$, or the (final) action uses

$*n* where *n* denote the mid-rule action. In that case its nonterminal is rather named @*n*:

exp: { a(); } "b" { $$ = c(); } { d(); } "e" { f = $1; };

is translated into

@1: empty { a(); };

@2: empty { $$ = c(); };

$@3: empty { d(); };

exp: @1 "b" @2 $@3 "e" { f = $1; }

There are probably two errors in the above example: the first mid-rule action does not generate a value (it does not use $$ although the final action uses it), and the value of the second one is not used (the final action does not use $3). Bison reports these errors when the midrule-value warnings are enabled (see [Chapter 9 [Invoking Bison], page 149](#_bookmark194)):

$ bison -Wmidrule-value mid.y mid.y:2.6-13: warning: unset value: $$

exp: { a(); } "b" { $$ = c(); } { d(); } "e" { f = $1; };

^^^^^^^^

mid.y:2.19-31: warning: unused value: $3

exp: { a(); } "b" { $$ = c(); } { d(); } "e" { f = $1; };

^^^^^^^^^^^^^

It is sometimes useful to turn mid-rule actions into regular actions, e.g., to factor them, or to escape from their limitations. For instance, as an alternative to *typed* mid-rule action, you may bury the mid-rule action inside a nonterminal symbol and to declare a printer and a destructor for that symbol:

type <context> let

destructor { pop\_context ($$); } let printer { print\_context (yyo, $$); } let



stmt:

let stmt

{

$$ = $2; pop\_context ($let);

};

let:

"let" ’(’ var ’)’

{

$let = push\_context (); declare\_variable ($var);

};

#### Conflicts due to Mid-Rule Actions

Taking action before a rule is completely recognized often leads to conflicts since the parser must commit to a parse in order to execute the action. For example, the following two rules, without mid-rule actions, can coexist in a working parser because the parser can shift the open-brace token and look at what follows before deciding whether there is a declaration or not:

compound:

’{’ declarations statements ’}’

| ’{’ statements ’}’

;

But when we add a mid-rule action as follows, the rules become nonfunctional:

compound:

{ prepare\_for\_local\_variables (); } ’{’ declarations statements ’}’

| ’{’ statements ’}’

;

Now the parser is forced to decide whether to run the mid-rule action when it has read no farther than the open-brace. In other words, it must commit to using one rule or the other, without sufficient information to do it correctly. (The open-brace token is what is called the *lookahead* token at this time, since the parser is still deciding what to do about it. See [Section 5.1 [Lookahead Tokens], page 107](#_bookmark141).)

You might think that you could correct the problem by putting identical actions into the two rules, like this:

compound:

{ prepare\_for\_local\_variables (); } ’{’ declarations statements ’}’

| { prepare\_for\_local\_variables (); } ’{’ statements ’}’

;

But this does not help, because Bison does not realize that the two actions are identical. (Bison never tries to understand the C code in an action.)

If the grammar is such that a declaration can be distinguished from a statement by the first token (which is true in C), then one solution which does work is to put the action after the open-brace, like this:

compound:

’{’ { prepare\_for\_local\_variables (); } declarations statements ’}’

| ’{’ statements ’}’

;

Now the first token of the following declaration or statement, which would in any case tell Bison which rule to use, can still do so.

Another solution is to bury the action inside a nonterminal symbol which serves as a subroutine:

subroutine:

empty { prepare\_for\_local\_variables (); }

;

compound:

subroutine ’{’ declarations statements ’}’

| subroutine ’{’ statements ’}’

;

Now Bison can execute the action in the rule for subroutine without deciding which rule for compound it will eventually use.

## Tracking Locations

Though grammar rules and semantic actions are enough to write a fully functional parser, it can be useful to process some additional information, especially symbol locations.

The way locations are handled is defined by providing a data type, and actions to take when rules are matched.

#### Data Type of Locations

Defining a data type for locations is much simpler than for semantic values, since all tokens and groupings always use the same type.

You can specify the type of locations by defining a macro called YYLTYPE, just as you can specify the semantic value type by defining a YYSTYPE macro (see [Section 3.4.1 [Value](#_bookmark61) [Type], page 61](#_bookmark61)). When YYLTYPE is not defined, Bison uses a default structure type with four members:

typedef struct YYLTYPE

{

int first\_line; int first\_column; int last\_line; int last\_column;

} YYLTYPE;

When YYLTYPE is not defined, at the beginning of the parsing, Bison initializes all these fields to 1 for yylloc. To initialize yylloc with a custom location type (or to chose a different initialization), use the initial-action directive. See [Section 3.7.5 [Performing](#_bookmark94) [Actions before Parsing], page 77](#_bookmark94).

#### Actions and Locations

Actions are not only useful for defining language semantics, but also for describing the behavior of the output parser with locations.

The most obvious way for building locations of syntactic groupings is very similar to the way semantic values are computed. In a given rule, several constructs can be used to access the locations of the elements being matched. The location of the *n*th component of the right hand side is @*n*, while the location of the left hand side grouping is @$.

In addition, the named references construct @*name* and @[*name*] may also be used to address the symbol locations. See [Section 3.6 [Named References], page 74](#_bookmark85), for more infor- mation about using the named references construct.

Here is a basic example using the default data type for locations:

exp:

...

| exp ’/’ exp

{

@$.first\_column = @1.first\_column; @$.first\_line = @1.first\_line; @$.last\_column = @3.last\_column; @$.last\_line = @3.last\_line;

if ($3)

$$ = $1 / $3; else

{

$$ = 1;

fprintf (stderr, "d. d- d. d: division by zero", @3.first\_line, @3.first\_column, @3.last\_line, @3.last\_column);

}

}

As for semantic values, there is a default action for locations that is run each time a rule is matched. It sets the beginning of @$ to the beginning of the first symbol, and the end of @$ to the end of the last symbol.

With this default action, the location tracking can be fully automatic. The example above simply rewrites this way:

exp:

...

| exp ’/’ exp

{

if ($3)

$$ = $1 / $3; else

{

$$ = 1;

fprintf (stderr, "d. d- d. d: division by zero", @3.first\_line, @3.first\_column, @3.last\_line, @3.last\_column);

}

}

It is also possible to access the location of the lookahead token, if any, from a semantic action. This location is stored in yylloc. See [Section 4.8 [Special Features for Use in](#_bookmark136) [Actions], page 103](#_bookmark136).

#### Default Action for Locations

Actually, actions are not the best place to compute locations. Since locations are much more general than semantic values, there is room in the output parser to redefine the default action to take for each rule. The YYLLOC\_DEFAULT macro is invoked each time a rule is matched, before the associated action is run. It is also invoked while processing a syntax error, to compute the error’s location. Before reporting an unresolvable syntactic ambiguity, a GLR parser invokes YYLLOC\_DEFAULT recursively to compute the location of that ambiguity.

Most of the time, this macro is general enough to suppress location dedicated code from semantic actions.

The YYLLOC\_DEFAULT macro takes three parameters. The first one is the location of the grouping (the result of the computation). When a rule is matched, the second parameter identifies locations of all right hand side elements of the rule being matched, and the third parameter is the size of the rule’s right hand side. When a GLR parser reports an ambiguity, which of multiple candidate right hand sides it passes to YYLLOC\_DEFAULT is undefined. When processing a syntax error, the second parameter identifies locations of the symbols that were discarded during error processing, and the third parameter is the number of discarded symbols.

By default, YYLLOC\_DEFAULT is defined this way:

# define YYLLOC\_DEFAULT(Cur, Rhs, N) \

do \

if (N) \

{ \

(Cur).first\_line = YYRHSLOC(Rhs, 1).first\_line; \ (Cur).first\_column = YYRHSLOC(Rhs, 1).first\_column; \ (Cur).last\_line = YYRHSLOC(Rhs, N).last\_line; \ (Cur).last\_column = YYRHSLOC(Rhs, N).last\_column; \

} \

else \

{ \

(Cur).first\_line = (Cur).last\_line = \ YYRHSLOC(Rhs, 0).last\_line; \ (Cur).first\_column = (Cur).last\_column = \ YYRHSLOC(Rhs, 0).last\_column; \

} \

while (0)

where YYRHSLOC (rhs, k) is the location of the *k*th symbol in *rhs* when *k* is positive, and the location of the symbol just before the reduction when *k* and *n* are both zero.

When defining YYLLOC\_DEFAULT, you should consider that:

All arguments are free of side-effects. However, only the first one (the result) should be modified by YYLLOC\_DEFAULT.

*•*

For consistency with semantic actions, valid indexes within the right hand side range from 1 to *n*. When *n* is zero, only 0 is a valid index, and it refers to the symbol just before the reduction. During error processing *n* is always positive.

*•*

Your macro should parenthesize its arguments, if need be, since the actual arguments may not be surrounded by parentheses. Also, your macro should expand to something that can be used as a single statement when it is followed by a semicolon.

*•*

## Named References

As described in the preceding sections, the traditional way to refer to any semantic value or location is a *positional reference*, which takes the form $*n*, $$, @*n*, and @$. However, such a reference is not very descriptive. Moreover, if you later decide to insert or remove symbols in the right-hand side of a grammar rule, the need to renumber such references can be tedious and error-prone.

To avoid these issues, you can also refer to a semantic value or location using a *named reference*. First of all, original symbol names may be used as named references. For example:

invocation: op ’(’ args ’)’

{ $invocation = new\_invocation ($op, $args, @invocation); }

Positional and named references can be mixed arbitrarily. For example:

invocation: op ’(’ args ’)’

{ $$ = new\_invocation ($op, $args, @$); }

However, sometimes regular symbol names are not sufficient due to ambiguities:

exp: exp ’/’ exp

{ $exp = $exp / $exp; } // $exp is ambiguous.

exp: exp ’/’ exp

{ $$ = $1 / $exp; } // One usage is ambiguous.

exp: exp ’/’ exp

{ $$ = $1 / $3; } // No error.

When ambiguity occurs, explicitly declared names may be used for values and locations. Ex- plicit names are declared as a bracketed name after a symbol appearance in rule definitions. For example:

exp[result]: exp[left] ’/’ exp[right]

{ $result = $left / $right; }

In order to access a semantic value generated by a mid-rule action, an explicit name may also be declared by putting a bracketed name after the closing brace of the mid-rule action code:

exp[res]: exp[x] ’+’ {$left = $x;}[left] exp[right]

{ $res = $left + $right; }

In references, in order to specify names containing dots and dashes, an explicit bracketed syntax $[name] and @[name] must be used:

if-stmt: "if" ’(’ expr ’)’ "then" then.stmt ’;’

{ $[if-stmt] = new\_if\_stmt ($expr, $[then.stmt]); }

It often happens that named references are followed by a dot, dash or other C punctuation marks and operators. By default, Bison will read ‘$name.suffix’ as a reference to symbol value $name followed by ‘.suffix’, i.e., an access to the suffix field of the semantic value.

In order to force Bison to recognize ‘name.suffix’ in its entirety as the name of a semantic value, the bracketed syntax ‘$[name.suffix]’ must be used.

The named references feature is experimental. More user feedback will help to stabilize

it.

## Bison Declarations

The *Bison declarations* section of a Bison grammar defines the symbols used in formulating the grammar and the data types of semantic values. See [Section 3.2 [Symbols], page 57](#_bookmark52).

All token type names (but not single-character literal tokens such as ’+’ and ’\*’) must be declared. Nonterminal symbols must be declared if you need to specify which data type to use for the semantic value (see [Section 3.4.2 [More Than One Value Type], page 62](#_bookmark63)).

The first rule in the grammar file also specifies the start symbol, by default. If you want some other symbol to be the start symbol, you must declare it explicitly (see [Section 1.1](#_bookmark4) [[Languages and Context-Free Grammars], page 17](#_bookmark4)).

#### Require a Version of Bison

You may require the minimum version of Bison to process the grammar. If the requirement is not met, bison exits with an error (exit status 63).

require "*version*"

#### Token Type Names

The basic way to declare a token type name (terminal symbol) is as follows:

token *name*

Bison will convert this into a #define directive in the parser, so that the function yylex

(if it is in this file) can use the name *name* to stand for this token type’s code.

Alternatively, you can use left, right, precedence, or nonassoc instead of token, if you wish to specify associativity and precedence. See [Section 3.7.3 [Operator](#_bookmark91) [Precedence], page 76](#_bookmark91).

You can explicitly specify the numeric code for a token type by appending a nonnegative decimal or hexadecimal integer value in the field immediately following the token name:

token NUM 300

token XNUM 0x12d // a GNU extension

It is generally best, however, to let Bison choose the numeric codes for all token types. Bison will automatically select codes that don’t conflict with each other or with normal characters.

In the event that the stack type is a union, you must augment the token or other token declaration to include the data type alternative delimited by angle-brackets (see [Section 3.4.2 [More Than One Value Type], page 62](#_bookmark63)).

For example:

union { /\* define stack type \*/ double val;

symrec \*tptr;

}

token <val> NUM /\* define token NUM and its type \*/

You can associate a literal string token with a token type name by writing the literal string at the end of a token declaration which declares the name. For example:

token arrow "=>"

For example, a grammar for the C language might specify these names with equivalent literal string tokens:

token <operator> OR "||" token <operator> LE 134 "<=" left OR "<="

Once you equate the literal string and the token name, you can use them interchangeably in further declarations or the grammar rules. The yylex function can use the token name or the literal string to obtain the token type code number (see [Section 4.6.1 [Calling Convention],](#_bookmark127) [page 99](#_bookmark127)). Syntax error messages passed to yyerror from the parser will reference the literal string instead of the token name.

The token numbered as 0 corresponds to end of file; the following line allows for nicer error messages referring to “end of file” instead of “$end”:

token END 0 "end of file"

#### Operator Precedence

Use the left, right, nonassoc, or precedence declaration to declare a token and specify its precedence and associativity, all at once. These are called *precedence declara- tions*. See [Section 5.3 [Operator Precedence], page 109](#_bookmark145), for general information on operator precedence.

The syntax of a precedence declaration is nearly the same as that of token: either

left *symbols*...

or

left <*type*> *symbols*...

And indeed any of these declarations serves the purposes of token. But in addition,

they specify the associativity and relative precedence for all the *symbols*:

The associativity of an operator *op* determines how repeated uses of the operator nest: whether ‘*x op y op z*’ is parsed by grouping *x* with *y* first or by grouping *y* with *z* first. left specifies left-associativity (grouping *x* with *y* first) and right specifies right-associativity (grouping *y* with *z* first). nonassoc specifies no associativity, which means that ‘*x op y op z*’ is considered a syntax error.

*•*

precedence gives only precedence to the *symbols*, and defines no associativity at all. Use this to define precedence only, and leave any potential conflict due to associativity enabled.

The precedence of an operator determines how it nests with other operators. All the tokens declared in a single precedence declaration have equal precedence and nest together according to their associativity. When two tokens declared in different prece- dence declarations associate, the one declared later has the higher precedence and is grouped first.

*•*

For backward compatibility, there is a confusing difference between the argument lists of token and precedence declarations. Only a token can associate a literal string with a

token type name. A precedence declaration always interprets a literal string as a reference to a separate token. For example:

left OR "<=" // Does not declare an alias.

left OR 134 "<=" 135 // Declares 134 for OR and 135 for "<=".

#### Nonterminal Symbols

When you use union to specify multiple value types, you must declare the value type of each nonterminal symbol for which values are used. This is done with a type declaration, like this:

type <*type*> *nonterminal*...

Here *nonterminal* is the name of a nonterminal symbol, and *type* is the name given in the union to the alternative that you want (see [Section 3.4.4 [The Union Declaration],](#_bookmark66) [page 63](#_bookmark66)). You can give any number of nonterminal symbols in the same type declaration, if they have the same value type. Use spaces to separate the symbol names.

You can also declare the value type of a terminal symbol. To do this, use the same <*type*> construction in a declaration for the terminal symbol. All kinds of token declarations allow

<*type*>.

#### Performing Actions before Parsing

Sometimes your parser needs to perform some initializations before parsing. The

initial-action directive allows for such arbitrary code.

initial-action *{ code }*

[Directive]

Declare that the braced *code* must be invoked before parsing each time yyparse is

called. The *code* may use $$ (or $<*tag*>$) and @$ — initial value and location of the lookahead — and the parse-param.

For instance, if your locations use a file name, you may use parse-param { char const \*file\_name }; initial-action

{

@$.initialize (file\_name);

};

#### Freeing Discarded Symbols

During error recovery (see [Chapter 6 [Error Recovery], page 127](#_bookmark170)), symbols already pushed on the stack and tokens coming from the rest of the file are discarded until the parser falls on its feet. If the parser runs out of memory, or if it returns via YYABORT or YYACCEPT, all the symbols on the stack must be discarded. Even if the parser succeeds, it must discard the start symbol.

When discarded symbols convey heap based information, this memory is lost. While this behavior can be tolerable for batch parsers, such as in traditional compilers, it is unac- ceptable for programs like shells or protocol implementations that may parse and execute indefinitely.

The destructor directive defines code that is called when a symbol is automatically discarded.

destructor *{ code } symbols*

[Directive]

Invoke the braced *code* whenever the parser discards one of the *symbols*. Within

*code*, $$ (or $<*tag*>$) designates the semantic value associated with the discarded symbol, and @$ designates its location. The additional parser parameters are also available (see [Section 4.1 [The Parser Function yyparse], page 97](#_bookmark120)).

When a symbol is listed among *symbols*, its destructor is called a per-symbol destructor. You may also define a per-type destructor by listing a semantic type tag among *symbols*. In that case, the parser will invoke this *code* whenever it discards any grammar symbol that has that semantic type tag unless that symbol has its own per-symbol destructor.

Finally, you can define two different kinds of default destructors. You can place each of <\*> and <> in the *symbols* list of exactly one destructor declaration in your grammar file. The parser will invoke the *code* associated with one of these whenever it discards any user-defined grammar symbol that has no per-symbol and no per-type destructor. The parser uses the *code* for <\*> in the case of such a grammar symbol for which you have formally declared a semantic type tag ( type counts as such a declaration, but $<tag>$ does not). The parser uses the *code* for <> in the case of such a grammar symbol that has no declared semantic type tag.

For example:

union { char \*string; } token <string> STRING1 STRING2 type <string> string1 string2 union { char character; } token <character> CHR

type <character> chr token TAGLESS

destructor { } <character> destructor { free ($$); } <\*>

destructor { free ($$); printf ("d", @$.first\_line); } STRING1 string1 destructor { printf ("Discarding tagless symbol.\n"); } <>

guarantees that, when the parser discards any user-defined symbol that has a semantic type tag other than <character>, it passes its semantic value to free by default. However, when the parser discards a STRING1 or a string1, it uses the third destructor, which frees it and prints its line number to stdout (free is invoked only once). Finally, the parser merely prints a message whenever it discards any symbol, such as TAGLESS, that has no semantic type tag.

A Bison-generated parser invokes the default destructors only for user-defined as opposed to Bison-defined symbols. For example, the parser will not invoke either kind of default destructor for the special Bison-defined symbols $accept, $undefined, or

$end (see [Appendix A [Bison Symbols], page 189](#_bookmark242)), none of which you can reference in your grammar. It also will not invoke either for the error token (see [Appendix A [error],](#_bookmark242) [page 189](#_bookmark242)), which is always defined by Bison regardless of whether you reference it in your grammar. However, it may invoke one of them for the end token (token 0) if you redefine it from $end to, for example, END:

token END 0

Finally, Bison will never invoke a destructor for an unreferenced mid-rule semantic value (see [Section 3.4.8 [Actions in Mid-Rule], page 66](#_bookmark72)). That is, Bison does not consider a mid-rule to have a semantic value if you do not reference $$ in the mid-rule’s action or

$*n* (where *n* is the right-hand side symbol position of the mid-rule) in any later action in that rule. However, if you do reference either, the Bison-generated parser will invoke the

<>  destructor whenever it discards the mid-rule symbol.

*Discarded symbols* are the following:

* + - * stacked symbols popped during the first phase of error recovery,
      * incoming terminals during the second phase of error recovery,

the current lookahead and the entire stack (except the current right-hand side symbols) when the parser returns immediately, and

*•*

the current lookahead and the entire stack (including the current right-hand side sym- bols) when the C++ parser (lalr1.cc) catches an exception in parse,

*•*

* + - * the start symbol, when the parser succeeds.

The parser can *return immediately* because of an explicit call to YYABORT or YYACCEPT, or failed error recovery, or memory exhaustion.

Right-hand side symbols of a rule that explicitly triggers a syntax error via YYERROR are not discarded automatically. As a rule of thumb, destructors are invoked only when user actions cannot manage the memory.

#### Printing Semantic Values

When run-time traces are enabled (see [Section 8.4 [Tracing Your Parser], page 143](#_bookmark188)), the parser reports its actions, such as reductions. When a symbol involved in an action is reported, only its kind is displayed, as the parser cannot know how semantic values should be formatted.

The printer directive defines code that is called when a symbol is reported. Its syntax is the same as destructor (see [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95)).

printer *{ code } symbols*

[Directive]

Invoke the braced *code* whenever the parser displays one of the *symbols*. Within

*code*, yyoutput denotes the output stream (a FILE\* in C, and an std::ostream& in C++), $$ (or $<*tag*>$) designates the semantic value associated with the symbol, and @$ its location. The additional parser parameters are also available (see [Section 4.1](#_bookmark120) [[The Parser Function yyparse], page 97](#_bookmark120)).

The *symbols* are defined as for destructor (see [Section 3.7.6 [Freeing Discarded](#_bookmark95) [Symbols], page 77](#_bookmark95).): they can be per-type (e.g., ‘<ival>’), per-symbol (e.g., ‘exp’,

‘NUM’, ‘"float"’), typed per-default (i.e., ‘<\*>’, or untyped per-default (i.e., ‘<>’).

For example:

union { char \*string; } token <string> STRING1 STRING2 type <string> string1 string2

union { char character; } token <character> CHR type <character> chr token TAGLESS

printer { fprintf (yyoutput, "’c’", $$); } <character> printer { fprintf (yyoutput, "&p", $$); } <\*>

printer { fprintf (yyoutput, "\"s\"", $$); } STRING1 string1 printer { fprintf (yyoutput, "<>"); } <>

guarantees that, when the parser print any symbol that has a semantic type tag other than <character>, it display the address of the semantic value by default. However, when the parser displays a STRING1 or a string1, it formats it as a string in double quotes. It performs only the second printer in this case, so it prints only once. Finally, the parser print ‘<>’ for any symbol, such as TAGLESS, that has no semantic type tag. See [Section 8.4.2](#_bookmark191) [[Enabling Debug Traces for mfcalc], page 144](#_bookmark191), for a complete example.

#### Suppressing Conflict Warnings

Bison normally warns if there are any conflicts in the grammar (see [Section 5.2 [Shift/Reduce](#_bookmark143) [Conflicts], page 108](#_bookmark143)), but most real grammars have harmless shift/reduce conflicts which are resolved in a predictable way and would be difficult to eliminate. It is desirable to suppress the warning about these conflicts unless the number of conflicts changes. You can do this with the expect declaration.

The declaration looks like this:

expect *n*

Here *n* is a decimal integer. The declaration says there should be *n* shift/reduce conflicts and no reduce/reduce conflicts. Bison reports an error if the number of shift/reduce conflicts differs from *n*, or if there are any reduce/reduce conflicts.

For deterministic parsers, reduce/reduce conflicts are more serious, and should be elim- inated entirely. Bison will always report reduce/reduce conflicts for these parsers. With GLR parsers, however, both kinds of conflicts are routine; otherwise, there would be no need to use GLR parsing. Therefore, it is also possible to specify an expected number of reduce/reduce conflicts in GLR parsers, using the declaration:

expect-rr *n*

In general, using expect involves these steps:

Compile your grammar without expect. Use the ‘-v’ option to get a verbose list of where the conflicts occur. Bison will also print the number of conflicts.

*•*

Check each of the conflicts to make sure that Bison’s default resolution is what you really want. If not, rewrite the grammar and go back to the beginning.

*•*

Add an expect declaration, copying the number *n* from the number which Bison printed. With GLR parsers, add an expect-rr declaration as well.

*•*

Now Bison will report an error if you introduce an unexpected conflict, but will keep silent otherwise.

#### The Start-Symbol

Bison assumes by default that the start symbol for the grammar is the first nonterminal specified in the grammar specification section. The programmer may override this restriction with the start declaration as follows:

start *symbol*

#### A Pure (Reentrant) Parser

A *reentrant* program is one which does not alter in the course of execution; in other words, it consists entirely of *pure* (read-only) code. Reentrancy is important whenever asynchronous execution is possible; for example, a nonreentrant program may not be safe to call from a signal handler. In systems with multiple threads of control, a nonreentrant program must be called only within interlocks.

Normally, Bison generates a parser which is not reentrant. This is suitable for most uses, and it permits compatibility with Yacc. (The standard Yacc interfaces are inherently nonreentrant, because they use statically allocated variables for communication with yylex, including yylval and yylloc.)

Alternatively, you can generate a pure, reentrant parser. The Bison declaration ‘define api.pure’ says that you want the parser to be reentrant. It looks like this:

define api.pure full

The result is that the communication variables yylval and yylloc become local variables in yyparse, and a different calling convention is used for the lexical analyzer function yylex. See [Section 4.6.4 [Calling Conventions for Pure Parsers], page 101](#_bookmark132), for the details of this. The variable yynerrs becomes local in yyparse in pull mode but it becomes a member of yypstate in push mode. (see [Section 4.7 [The Error Reporting Function yyerror],](#_bookmark134) [page 102](#_bookmark134)). The convention for calling yyparse itself is unchanged.

Whether the parser is pure has nothing to do with the grammar rules. You can generate either a pure parser or a nonreentrant parser from any valid grammar.

#### A Push Parser

A pull parser is called once and it takes control until all its input is completely parsed. A push parser, on the other hand, is called each time a new token is made available.

A push parser is typically useful when the parser is part of a main event loop in the client’s application. This is typically a requirement of a GUI, when the main event loop needs to be triggered within a certain time period.

Normally, Bison generates a pull parser. The following Bison declaration says that you want the parser to be a push parser (see [Section 3.7.13 [api.push-pull], page 86](#_bookmark109)):

define api.push-pull push

In almost all cases, you want to ensure that your push parser is also a pure parser (see [Section 3.7.10 [A Pure (Reentrant) Parser], page 81](#_bookmark102)). The only time you should create an impure push parser is to have backwards compatibility with the impure Yacc pull mode interface. Unless you know what you are doing, your declarations should look like this:

define api.pure full define api.push-pull push

There is a major notable functional difference between the pure push parser and the impure push parser. It is acceptable for a pure push parser to have many parser instances, of the same type of parser, in memory at the same time. An impure push parser should only use one parser at a time.

When a push parser is selected, Bison will generate some new symbols in the generated parser. yypstate is a structure that the generated parser uses to store the parser’s state. yypstate\_new is the function that will create a new parser instance. yypstate\_delete will free the resources associated with the corresponding parser instance. Finally, yypush\_parse is the function that should be called whenever a token is available to provide the parser. A trivial example of using a pure push parser would look like this:

int status;

yypstate \*ps = yypstate\_new (); do {

status = yypush\_parse (ps, yylex (), NULL);

} while (status == YYPUSH\_MORE); yypstate\_delete (ps);

If the user decided to use an impure push parser, a few things about the generated parser will change. The yychar variable becomes a global variable instead of a variable in the yypush\_parse function. For this reason, the signature of the yypush\_parse function is changed to remove the token as a parameter. A nonreentrant push parser example would thus look like this:

extern int yychar; int status;

yypstate \*ps = yypstate\_new (); do {

yychar = yylex ();

status = yypush\_parse (ps);

} while (status == YYPUSH\_MORE); yypstate\_delete (ps);

That’s it. Notice the next token is put into the global variable yychar for use by the next invocation of the yypush\_parse function.

Bison also supports both the push parser interface along with the pull parser interface in the same generated parser. In order to get this functionality, you should replace the ‘define api.push-pull push’ declaration with the ‘define api.push-pull both’ dec- laration. Doing this will create all of the symbols mentioned earlier along with the two extra symbols, yyparse and yypull\_parse. yyparse can be used exactly as it normally would be used. However, the user should note that it is implemented in the generated parser by calling yypull\_parse. This makes the yyparse function that is generated with the ‘define api.push-pull both’ declaration slower than the normal yyparse function. If the user calls the yypull\_parse function it will parse the rest of the input stream. It is possible to yypush\_parse tokens to select a subgrammar and then yypull\_parse the rest of the input stream. If you would like to switch back and forth between between parsing styles, you would have to write your own yypull\_parse function that knows when to quit looking for input. An example of using the yypull\_parse function would look like this:

yypstate \*ps = yypstate\_new ();

yypull\_parse (ps); /\* Will call the lexer \*/ yypstate\_delete (ps);

Adding the ‘define api.pure’ declaration does exactly the same thing to the generated parser with ‘define api.push-pull both’ as it did for ‘define api.push-pull push’.

#### Bison Declaration Summary

Here is a summary of the declarations used to define a grammar:

union [Directive]

Declare the collection of data types that semantic values may have (see [Section 3.4.4](#_bookmark66) [[The Union Declaration], page 63](#_bookmark66)).

token [Directive]

Declare a terminal symbol (token type name) with no precedence or associativity specified (see [Section 3.7.2 [Token Type Names], page 75](#_bookmark89)).

right [Directive]

Declare a terminal symbol (token type name) that is right-associative (see [Section 3.7.3 [Operator Precedence], page 76](#_bookmark91)).

left [Directive]

Declare a terminal symbol (token type name) that is left-associative (see [Section 3.7.3](#_bookmark91) [[Operator Precedence], page 76](#_bookmark91)).

nonassoc [Directive]

Declare a terminal symbol (token type name) that is nonassociative (see [Section 3.7.3](#_bookmark91) [[Operator Precedence], page 76](#_bookmark91)). Using it in a way that would be associative is a syntax error.

type [Directive]

Declare the type of semantic values for a nonterminal symbol (see [Section 3.7.4 [Non-](#_bookmark93) [terminal Symbols], page 77](#_bookmark93)).

start [Directive]

Specify the grammar’s start symbol (see [Section 3.7.9 [The Start-Symbol], page 81](#_bookmark101)).

expect [Directive]

Declare the expected number of shift-reduce conflicts (see [Section 3.7.8 [Suppressing](#_bookmark100) [Conflict Warnings], page 80](#_bookmark100)).

In order to change the behavior of bison, use the following directives:

code *{code}*

code *qualifier {code}*

[Directive] [Directive]

Insert *code* verbatim into the output parser source at the default location or at the

location specified by *qualifier*. See [Section 3.7.14 [%code Summary], page 92](#_bookmark115).

debug [Directive]

Instrument the parser for traces. Obsoleted by ‘ define parse.trace’. See [Section 8.4 [Tracing Your Parser], page 143](#_bookmark188).

define *variable *define *variable value *define *variable value*

*{ }*

define *variable* "*value*"

[Directive] [Directive] [Directive] [Directive]

Define a variable to adjust Bison’s behavior. See [Section 3.7.13 [%define Summary],](#_bookmark109) [page 86](#_bookmark109).

defines [Directive]

Write a parser header file containing macro definitions for the token type names de- fined in the grammar as well as a few other declarations. If the parser implementation file is named *name*.c then the parser header file is named *name*.h.

For C parsers, the parser header file declares YYSTYPE unless YYSTYPE is already defined as a macro or you have used a <*type*> tag without using union. Therefore, if you are using a union (see [Section 3.4.2 [More Than One Value Type], page 62](#_bookmark63)) with components that require other definitions, or if you have defined a YYSTYPE macro or type definition (see [Section 3.4.1 [Data Types of Semantic Values], page 61](#_bookmark61)), you need to arrange for these definitions to be propagated to all modules, e.g., by putting them in a prerequisite header that is included both by your parser and by any other module that needs YYSTYPE.

Unless your parser is pure, the parser header file declares yylval as an external variable. See [Section 3.7.10 [A Pure (Reentrant) Parser], page 81](#_bookmark102).

If you have also used locations, the parser header file declares YYLTYPE and yylloc using a protocol similar to that of the YYSTYPE macro and yylval. See [Section 3.5](#_bookmark79) [[Tracking Locations], page 71](#_bookmark79).

This parser header file is normally essential if you wish to put the definition of yylex in a separate source file, because yylex typically needs to be able to refer to the above- mentioned declarations and to the token type codes. See [Section 4.6.2 [Semantic](#_bookmark129) [Values of Tokens], page 100](#_bookmark129).

If you have declared code requires or code provides, the output header also contains their code. See [Section 3.7.14 [%code Summary], page 92](#_bookmark115).

The generated header is protected against multiple inclusions with a C preprocessor guard: ‘YY\_*PREFIX*\_*FILE*\_INCLUDED’, where *PREFIX* and *FILE* are the prefix (see [Section 3.8 [Multiple Parsers in the Same Program], page 94](#_bookmark118)) and generated file name turned uppercase, with each series of non alphanumerical characters converted to a single underscore.

For instance with ‘define api.prefix {calc}’ and ‘defines "lib/parse.h"’, the header will be guarded as follows.

#ifndef YY\_CALC\_LIB\_PARSE\_H\_INCLUDED # define YY\_CALC\_LIB\_PARSE\_H\_INCLUDED

...

#endif /\* ! YY\_CALC\_LIB\_PARSE\_H\_INCLUDED \*/

defines *defines-file*

Same as above, but save in the file *defines-file*.

[Directive]

destructor [Directive]

Specify how the parser should reclaim the memory associated to discarded symbols. See [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95).

file-prefix "*prefix*" [Directive]

Specify a prefix to use for all Bison output file names. The names are chosen as if the grammar file were named *prefix*.y.

language "*language*" [Directive]

Specify the programming language for the generated parser. Currently supported languages include C, C++, and Java. *language* is case-insensitive.

locations [Directive]

Generate the code processing the locations (see [Section 4.8 [Special Features for Use](#_bookmark136) [in Actions], page 103](#_bookmark136)). This mode is enabled as soon as the grammar uses the special ‘@*n*’ tokens, but if your grammar does not use it, using ‘locations’ allows for more accurate syntax error messages.

name-prefix "*prefix*" [Directive]

Rename the external symbols used in the parser so that they start with *prefix* in- stead of ‘yy’. The precise list of symbols renamed in C parsers is yyparse, yylex, yyerror, yynerrs, yylval, yychar, yydebug, and (if locations are used) yylloc. If you use a push parser, yypush\_parse, yypull\_parse, yypstate, yypstate\_new and yypstate\_delete will also be renamed. For example, if you use ‘name-prefix "c\_"’, the names become c\_parse, c\_lex, and so on. For C++ parsers, see the ‘define api.namespace’ documentation in this section. See [Section 3.8 [Multiple](#_bookmark118) [Parsers in the Same Program], page 94](#_bookmark118).

no-lines [Directive]

Don’t generate any #line preprocessor commands in the parser implementation file. Ordinarily Bison writes these commands in the parser implementation file so that the C compiler and debuggers will associate errors and object code with your source file (the grammar file). This directive causes them to associate errors with the parser implementation file, treating it as an independent source file in its own right.

output "*file*"

Generate the parser implementation in *file*.

###### pure-parser

[Directive]

[Directive]

Deprecated version of ‘define api.pure’ (see [Section 3.7.13 [api.pure], page 86](#_bookmark109)), for which Bison is more careful to warn about unreasonable usage.

require "*version*" [Directive]

Require version *version* or higher of Bison. See [Section 3.7.1 [Require a Version of](#_bookmark88) [Bison], page 75](#_bookmark88).

skeleton "*file*"

Specify the skeleton to use.

[Directive]

If *file* does not contain a /, *file* is the name of a skeleton file in the Bison installation directory. If it does, *file* is an absolute file name or a file name relative to the directory of the grammar file. This is similar to how most shells resolve commands.

token-table [Directive]

Generate an array of token names in the parser implementation file. The name of the array is yytname; yytname[*i*] is the name of the token whose internal Bison token code number is *i*. The first three elements of yytname correspond to the predefined tokens "$end", "error", and "$undefined"; after these come the symbols defined in the grammar file.

The name in the table includes all the characters needed to represent the token in Bison. For single-character literals and literal strings, this includes the surrounding quoting characters and any escape sequences. For example, the Bison single-character literal ’+’ corresponds to a three-character name, represented in C as "’+’"; and the Bison two-character literal string "\\/" corresponds to a five-character name, represented in C as "\"\\\\/\"".

When you specify token-table, Bison also generates macro definitions for macros

YYNTOKENS, YYNNTS, and YYNRULES, and YYNSTATES:

YYNTOKENS

The highest token number, plus one.

YYNNTS The number of nonterminal symbols. YYNRULES The number of grammar rules, YYNSTATES

###### verbose

The number of parser states (see [Section 5.5 [Parser States], page 113](#_bookmark151)).

[Directive]

Write an extra output file containing verbose descriptions of the parser states and what is done for each type of lookahead token in that state. See [Section 8.1 [Under-](#_bookmark178) [standing Your Parser], page 133](#_bookmark178), for more information.

yacc [Directive]

Pretend the option --yacc was given, i.e., imitate Yacc, including its naming conven- tions. See [Section 9.1 [Bison Options], page 149](#_bookmark195), for more.

#### %define Summary

There are many features of Bison’s behavior that can be controlled by assigning the feature a single value. For historical reasons, some such features are assigned values by dedicated directives, such as start, which assigns the start symbol. However, newer such features are associated with variables, which are assigned by the define directive:

define *variable *define *variable value *define *variable value*

*{ }*

define *variable* "*value*"

Define *variable* to *value*.

[Directive] [Directive] [Directive] [Directive]

The type of the values depend on the syntax. Braces denote value in the target language (e.g., a namespace, a type, etc.). Keyword values (no delimiters) denote finite choice (e.g., a variation of a feature). String values denote remaining cases (e.g., a file name).

It is an error if a *variable* is defined by define multiple times, but see [Section 9.1](#_bookmark195) [[-D](#_bookmark195) *[name](#_bookmark195)*[[=](#_bookmark195)*[value](#_bookmark195)*[]], page 149](#_bookmark195).

The rest of this section summarizes variables and values that define accepts.

Some *variable*s take Boolean values. In this case, Bison will complain if the variable definition does not meet one of the following four conditions:

1. *value* is true
2. *value* is omitted (or "" is specified). This is equivalent to true.
3. *value* is false.
4. *variable* is never defined. In this case, Bison selects a default value.

What *variable*s are accepted, as well as their meanings and default values, depend on the selected target language and/or the parser skeleton (see [Section 3.7.12 [%language],](#_bookmark105) [page 83](#_bookmark105), see [Section 3.7.12 [%skeleton], page 83](#_bookmark105)). Unaccepted *variable*s produce an error. Some of the accepted *variable*s are described below.

define api.namespace *{namespace}*

* + Languages(s): C++

[Directive]

* + Purpose: Specify the namespace for the parser class. For example, if you specify:

define api.namespace {foo::bar}

Bison uses foo::bar verbatim in references such as:

foo::bar::parser::semantic\_type

However, to open a namespace, Bison removes any leading :: and then splits on any remaining occurrences:

namespace foo { namespace bar { class position;

class location;

} }

Accepted Values: Any absolute or relative C++ namespace reference without a trailing "::". For example, "foo" or "::foo::bar".

*•*

Default Value: The value specified by name-prefix, which defaults to yy. This usage of name-prefix is for backward compatibility and can be confus- ing since name-prefix also specifies the textual prefix for the lexical analyzer function. Thus, if you specify name-prefix, it is best to also specify ‘ define api.namespace’ so that name-prefix *only* affects the lexical analyzer function. For example, if you specify:

*•*

define api.namespace {foo} name-prefix "bar::"

The parser namespace is foo and yylex is referenced as bar::lex.

###### define api.location.type *{type}*

* + Language(s): C++, Java

*•*

[Directive]

Purpose: Define the location type. See [Section 10.1.3.3 [User Defined Location](#_bookmark207)

[Type], page 161](#_bookmark207).

* + Accepted Values: String
  + Default Value: none

History: Introduced in Bison 2.7 for C, C++ and Java. Introduced under the name location\_type for C++ in Bison 2.5 and for Java in Bison 2.4.

*•*

define api.prefix *{prefix}*

* + Language(s): All

*•*

[Directive]

Purpose: Rename exported symbols. See [Section 3.8 [Multiple Parsers in the](#_bookmark118)

[Same Program], page 94](#_bookmark118).

* + Accepted Values: String
  + Default Value: yy
  + History: introduced in Bison 2.6

define api.pure *purity*

* + Language(s): C

*•*

[Directive]

Purpose: Request a pure (reentrant) parser program. See [Section 3.7.10 [A Pure](#_bookmark102)

[(Reentrant) Parser], page 81](#_bookmark102).

* + Accepted Values: true, false, full

The value may be omitted: this is equivalent to specifying true, as is the case for Boolean values.

When define api.pure full is used, the parser is made reentrant. This changes the signature for yylex (see [Section 4.6.4 [Pure Calling], page 101](#_bookmark132)), and also that of yyerror when the tracking of locations has been activated, as shown below.

The true value is very similar to the full value, the only difference is in the sig- nature of yyerror on Yacc parsers without parse-param, for historical reasons.

I.e., if ‘locations  define api.pure’ is passed then the prototypes for yyerror are:

void yyerror (char const \*msg); // Yacc parsers. void yyerror (YYLTYPE \*locp, char const \*msg); // GLR parsers.

But if ‘locations  define api.pure  parse-param {int \*nastiness}’ is used, then both parsers have the same signature:

void yyerror (YYLTYPE \*llocp, int \*nastiness, char const \*msg);

(see [Section 4.7 [The Error Reporting Function yyerror], page 102](#_bookmark134))

* + Default Value: false
  + History: the full value was introduced in Bison 2.7

###### define api.push-pull *kind*

* + Language(s): C (deterministic parsers only)

*•*

[Directive]

Purpose: Request a pull parser, a push parser, or both. See [Section 3.7.11 [A](#_bookmark103)

[Push Parser], page 81](#_bookmark103).

* + Accepted Values: pull, push, both
  + Default Value: pull

###### define api.token.constructor

* + Language(s): C++

*•*

[Directive]

Purpose: When variant-based semantic values are enabled (see [Section 10.1.2.2](#_bookmark202)

[[C++ Variants], page 158](#_bookmark202)), request that symbols be handled as a whole (type, value, and possibly location) in the scanner. See [Section 10.1.5.2 [Complete](#_bookmark211) [Symbols], page 164](#_bookmark211), for details.

* + Accepted Values: Boolean.
  + Default Value: false
  + History: introduced in Bison 3.0

define api.token.prefix *{prefix}*

* + Languages(s): all

*•*

[Directive]

Purpose: Add a prefix to the token names when generating their definition in

the target language. For instance

token FILE for ERROR

define api.token.prefix {TOK\_}



start: FILE for ERROR;

generates the definition of the symbols TOK\_FILE, TOK\_for, and TOK\_ERROR in the generated source files. In particular, the scanner must use these prefixed token names, while the grammar itself may still use the short names (as in the sample rule given above). The generated informational files (\*.output, \*.xml,

\*.dot) are not modified by this prefix.

Bison also prefixes the generated member names of the semantic value union. See [Section 3.4.3 [Generating the Semantic Value Type], page 62](#_bookmark64), for more details. See [Section 10.1.6.3 [Calc++ Parser], page 167,](#_bookmark214) and [Section 10.1.6.4 [Calc++ Scan-](#_bookmark217) [ner], page 169](#_bookmark217), for a complete example.

Accepted Values: Any string. Should be a valid identifier prefix in the target language, in other words, it should typically be an identifier itself (sequence of letters, underscores, and —not at the beginning— digits).

*•*

* + Default Value: empty
  + History: introduced in Bison 3.0

define api.value.type *support*

define api.value.type *{type}*

* + Language(s): all
  + Purpose: The type for semantic values.
  + Accepted Values:

[Directive] [Directive]

‘{}’ This grammar has no semantic value at all. This is not properly supported yet.

‘union-directive’ (C, C++)

The type is defined thanks to the union directive. You don’t have to define api.value.type in that case, using union suffices. See [Section 3.4.4 [The Union Declaration], page 63](#_bookmark66). For instance:

define api.value.type union-directive

union

{

int ival; char \*sval;

}

‘union’ (C, C++)

token <ival> INT "integer" token <sval> STR "string"

The symbols are defined with type names, from which Bison will generate a union. For instance:

define api.value.type union token <int> INT "integer" token <char \*> STR "string"

Most C++ objects cannot be stored in a union, use ‘variant’ instead.

‘variant’ (C++)

This is similar to union, but special storage techniques are used to allow any kind of C++ object to be used. For instance:

define api.value.type variant token <int> INT "integer" token <std::string> STR "string"

See [Section 10.1.2.2 [C++ Variants], page 158](#_bookmark202). ‘{*type*}’ Use this *type* as semantic value.

code requires

{

struct my\_value

{

enum

{

is\_int, is\_str

} kind; union

{

int ival; char \*sval;

} u;

};

}

* + Default Value:

define api.value.type {struct my\_value} token <u.ival> INT "integer"

token <u.sval> STR "string"

* + - union-directive if union is used, otherwise . . .

int if type tags are used (i.e., ‘token <*type*>...’ or ‘type <*type*>...’ is used), otherwise . . .

*−*

* + - undefined.
  + History: introduced in Bison 3.0. Was introduced for Java only in 2.3b as stype.

###### define api.value.union.name *name*

* + Language(s): C

*•*

[Directive]

Purpose: The tag of the generated union (*not* the name of the typedef). This

variable is set to *id* when ‘union *id*’ is used. There is no clear reason to give this union a name.

* + Accepted Values: Any valid identifier.
  + Default Value: YYSTYPE.
  + History: Introduced in Bison 3.0.3.

###### define location\_type

Obsoleted by api.location.type since Bison 2.7.

###### define lr.default-reduction *when*

* + Language(s): all

*•*

[Directive]

[Directive]

Purpose: Specify the kind of states that are permitted to contain default reduc-

tions. See [Section 5.8.2 [Default Reductions], page 119](#_bookmark159). (The ability to specify where default reductions should be used is experimental. More user feedback will help to stabilize it.)

* + Accepted Values: most, consistent, accepting
  + Default Value:
* accepting if lr.type is canonical-lr.
* most otherwise.

History: introduced as lr.default-reductions in 2.5, renamed as

*•*

lr.default-reduction in 3.0.

###### define lr.keep-unreachable-state

* + Language(s): all

*•*

[Directive]

Purpose: Request that Bison allow unreachable parser states to remain in the

parser tables. See [Section 5.8.4 [Unreachable States], page 122](#_bookmark164).

* + Accepted Values: Boolean
  + Default Value: false

History: introduced as lr.keep\_unreachable\_states in 2.3b, renamed as lr.keep-unreachable-states in 2.5, and as lr.keep-unreachable-state in 3.0.

*•*

define lr.type *type*

* + Language(s): all

*•*

[Directive]

Purpose: Specify the type of parser tables within the LR(1) family. See

[Section 5.8.1 [LR Table Construction], page 118](#_bookmark157).

* + Accepted Values: lalr, ielr, canonical-lr
  + Default Value: lalr

define *namespace namespace*

*{ }*

Obsoleted by api.namespace

###### define parse.assert

* + Languages(s): C++

*•*

[Directive] [Directive]

Purpose: Issue runtime assertions to catch invalid uses. In C++, when variants are

used (see [Section 10.1.2.2 [C++ Variants], page 158](#_bookmark202)), symbols must be constructed and destroyed properly. This option checks these constraints.

* + Accepted Values: Boolean
  + Default Value: false

define parse.error *verbosity*

* + Languages(s): all

*•*

[Directive]

Purpose: Control the kind of error messages passed to the error reporting func-

tion. See [Section 4.7 [The Error Reporting Function yyerror], page 102](#_bookmark134).

* + Accepted Values:
* simple Error messages passed to yyerror are simply "syntax error". verbose Error messages report the unexpected token, and possibly the ex-

*•*

pected ones. However, this report can often be incorrect when LAC is not enabled (see [Section 5.8.3 [LAC], page 121](#_bookmark162)).

* + Default Value: simple

###### define parse.lac *when*

* + Languages(s): C (deterministic parsers only)

*•*

[Directive]

Purpose: Enable LAC (lookahead correction) to improve syntax error handling.

See [Section 5.8.3 [LAC], page 121](#_bookmark162).

* + Accepted Values: none, full
  + Default Value: none

###### define parse.trace

* + Languages(s): C, C++, Java

*•*

[Directive]

Purpose: Require parser instrumentation for tracing. See [Section 8.4 [Tracing](#_bookmark188)

[Your Parser], page 143](#_bookmark188).

In C/C++, define the macro YYDEBUG (or *prefix*DEBUG with ‘ define api.prefix {*prefix*}’), see [Section 3.8 [Multiple Parsers in the Same](#_bookmark118) [Program], page 94](#_bookmark118)) to 1 in the parser implementation file if it is not already defined, so that the debugging facilities are compiled.

* + Accepted Values: Boolean
  + Default Value: false

#### %code Summary

The code directive inserts code verbatim into the output parser source at any of a pre- defined set of locations. It thus serves as a flexible and user-friendly alternative to the traditional Yacc prologue, {*code *}. This section summarizes the functionality of code for the various target languages supported by Bison. For a detailed discussion of how to use

code in place of {*code *} for C/C++ and why it is advantageous to do so, see [Section 3.1.2](#_bookmark48) [[Prologue Alternatives], page 52](#_bookmark48).

code *{code}*

[Directive]

This is the unqualified form of the code directive. It inserts *code* verbatim at a

language-dependent default location in the parser implementation.

For C/C++, the default location is the parser implementation file after the usual contents of the parser header file. Thus, the unqualified form replaces {*code *} for most purposes.

For Java, the default location is inside the parser class.

code *qualifier {code}*

[Directive]

This is the qualified form of the code directive. *qualifier* identifies the purpose of

*code* and thus the location(s) where Bison should insert it. That is, if you need to specify location-sensitive *code* that does not belong at the default location selected by the unqualified code form, use this form instead.

For any particular qualifier or for the unqualified form, if there are multiple occurrences of the code directive, Bison concatenates the specified code in the order in which it appears in the grammar file.

Not all qualifiers are accepted for all target languages. Unaccepted qualifiers produce an error. Some of the accepted qualifiers are:

requires

provides

top

* Language(s): C, C++

Purpose: This is the best place to write dependency code required for YYSTYPE and YYLTYPE. In other words, it’s the best place to define types referenced in union directives. If you use #define to override Bison’s de- fault YYSTYPE and YYLTYPE definitions, then it is also the best place. How- ever you should rather define api.value.type and api.location.type.

*•*

Location(s): The parser header file and the parser implementation file before the Bison-generated YYSTYPE and YYLTYPE definitions.

*•*

* Language(s): C, C++

Purpose: This is the best place to write additional definitions and decla- rations that should be provided to other modules.

*•*

Location(s): The parser header file and the parser implementation file after the Bison-generated YYSTYPE, YYLTYPE, and token definitions.

*•*

* Language(s): C, C++

Purpose: The unqualified code or code requires should usually be more appropriate than code top. However, occasionally it is necessary to insert code much nearer the top of the parser implementation file. For example:

*•*

code top {

#define \_GNU\_SOURCE

#include <stdio.h>

}

imports

* Location(s): Near the top of the parser implementation file.
* Language(s): Java
* Purpose: This is the best place to write Java import directives. Location(s): The parser Java file after any Java package directive and before any class definitions.

*•*

Though we say the insertion locations are language-dependent, they are technically skeleton-dependent. Writers of non-standard skeletons however should choose their loca- tions consistently with the behavior of the standard Bison skeletons.

## 3.8 Multiple Parsers in the Same Program

Most programs that use Bison parse only one language and therefore contain only one Bison parser. But what if you want to parse more than one language with the same program? Then you need to avoid name conflicts between different definitions of functions and variables such as yyparse, yylval. To use different parsers from the same compilation unit, you also need to avoid conflicts on types and macros (e.g., YYSTYPE) exported in the generated header.

The easy way to do this is to define the define variable api.prefix. With different api.prefixs it is guaranteed that headers do not conflict when included together, and that compiled objects can be linked together too. Specifying ‘define api.prefix {*prefix*}’ (or passing the option ‘-Dapi.prefix={*prefix*}’, see [Chapter 9 [Invoking Bison], page 149](#_bookmark194)) renames the interface functions and variables of the Bison parser to start with *prefix* instead of ‘yy’, and all the macros to start by *PREFIX* (i.e., *prefix* upper-cased) instead of ‘YY’.

The renamed symbols include yyparse, yylex, yyerror, yynerrs, yylval, yylloc, yychar and yydebug. If you use a push parser, yypush\_parse, yypull\_parse, yypstate, yypstate\_new and yypstate\_delete will also be renamed. The renamed macros include YYSTYPE, YYLTYPE, and YYDEBUG, which is treated specifically — more about this below.

For example, if you use ‘define api.prefix {c}’, the names become cparse, clex,

. . . , CSTYPE, CLTYPE, and so on.

The define variable api.prefix works in two different ways. In the implementation file, it works by adding macro definitions to the beginning of the parser implementation file, defining yyparse as *prefix*parse, and so on:

#define YYSTYPE CTYPE #define yyparse cparse #define yylval clval

...

YYSTYPE yylval; int yyparse (void);

This effectively substitutes one name for the other in the entire parser implementation file, thus the “original” names (yylex, YYSTYPE, . . . ) are also usable in the parser imple- mentation file.

However, in the parser header file, the symbols are defined renamed, for instance:

extern CSTYPE clval; int cparse (void);

The macro YYDEBUG is commonly used to enable the tracing support in parsers. To comply with this tradition, when api.prefix is used, YYDEBUG (not renamed) is used as a default value:

/\* Debug traces. \*/ #ifndef CDEBUG

# if defined YYDEBUG # if YYDEBUG

# define CDEBUG 1 # else

# define CDEBUG 0 # endif

# else

# define CDEBUG 0 # endif

#endif #if CDEBUG

extern int cdebug; #endif

Prior to Bison 2.6, a feature similar to api.prefix was provided by the obsolete directive name-prefix (see [Appendix A [Bison Symbols], page 189](#_bookmark242)) and the option --name-prefix (see [Section 9.1 [Bison Options], page 149](#_bookmark195)).

# Parser C-Language Interface

The Bison parser is actually a C function named yyparse. Here we describe the interface conventions of yyparse and the other functions that it needs to use.

Keep in mind that the parser uses many C identifiers starting with ‘yy’ and ‘YY’ for internal purposes. If you use such an identifier (aside from those in this manual) in an action or in epilogue in the grammar file, you are likely to run into trouble.

* 1. **The Parser Function** yyparse

You call the function yyparse to cause parsing to occur. This function reads tokens, executes actions, and ultimately returns when it encounters end-of-input or an unrecoverable syntax error. You can also write an action which directs yyparse to return immediately without reading further.

int yyparse (*void*) [Function]

The value returned by yyparse is 0 if parsing was successful (return is due to end-of- input).

The value is 1 if parsing failed because of invalid input, i.e., input that contains a syntax error or that causes YYABORT to be invoked.

The value is 2 if parsing failed due to memory exhaustion.

In an action, you can cause immediate return from yyparse by using these macros:

###### YYACCEPT

Return immediately with value 0 (to report success).

###### YYABORT

Return immediately with value 1 (to report failure).

[Macro] [Macro]

If you use a reentrant parser, you can optionally pass additional parameter information to it in a reentrant way. To do so, use the declaration parse-param:

parse-param *{argument-declaration} . . .*

[Directive]

Declare that one or more *argument-declaration* are additional yyparse arguments.

The *argument-declaration* is used when declaring functions or prototypes. The last identifier in *argument-declaration* must be the argument name.

Here’s an example. Write this in the parser:

parse-param {int \*nastiness} {int \*randomness}

Then call the parser like this:

{

int nastiness, randomness;

... /\* Store proper data in nastiness and randomness. \*/ value = yyparse (&nastiness, &randomness);

...

}

In the grammar actions, use expressions like this to refer to the data:

exp: ... { ...; \*randomness += 1; ... }

Using the following:

parse-param {int \*randomness}

Results in these signatures:

void yyerror (int \*randomness, const char \*msg); int yyparse (int \*randomness);

Or, if both define api.pure full (or just define api.pure) and locations are used:

void yyerror (YYLTYPE \*llocp, int \*randomness, const char \*msg); int yyparse (int \*randomness);

* 1. **The Push Parser Function** yypush\_parse

You call the function yypush\_parse to parse a single token. This function is available if either the ‘define api.push-pull push’ or ‘define api.push-pull both’ declaration is used. See [Section 3.7.11 [A Push Parser], page 81](#_bookmark103).

int yypush\_parse (*yypstate \*yyps*) [Function]

The value returned by yypush\_parse is the same as for yyparse with the following exception: it returns YYPUSH\_MORE if more input is required to finish parsing the grammar.

After yypush\_parse returns a status other than YYPUSH\_MORE, the parser instance

yyps may be reused for a new parse.

The fact that the parser state is reusable even after an error simplifies reuse. For example, a calculator application which parses each input line as an expression can just keep reusing the same yyps even if an input was invalid.

* 1. **The Pull Parser Function** yypull\_parse

You call the function yypull\_parse to parse the rest of the input stream. This function is available if the ‘define api.push-pull both’ declaration is used. See [Section 3.7.11 [A](#_bookmark103) [Push Parser], page 81](#_bookmark103).

int yypull\_parse (*yypstate \*yyps*)

The value returned by yypull\_parse is the same as for yyparse.

The parser instance yyps may be reused for new parses.

[Function]

* 1. **The Parser Create Function** yystate\_new

You call the function yypstate\_new to create a new parser instance. This function is available if either the ‘define api.push-pull push’ or ‘define api.push-pull both’ declaration is used. See [Section 3.7.11 [A Push Parser], page 81](#_bookmark103).

yypstate\* yypstate\_new (*void*) [Function]

The function will return a valid parser instance if there was memory available or 0 if no memory was available. In impure mode, it will also return 0 if a parser instance is currently allocated.

* 1. **The Parser Delete Function** yystate\_delete

You call the function yypstate\_delete to delete a parser instance. function is available if either the ‘define api.push-pull push’ or ‘define api.push-pull both’ declaration is used. See [Section 3.7.11 [A Push Parser], page 81](#_bookmark103).

void yypstate\_delete (*yypstate \*yyps*) [Function]

This function will reclaim the memory associated with a parser instance. After this call, you should no longer attempt to use the parser instance.

## The Lexical Analyzer Function yylex

The *lexical analyzer* function, yylex, recognizes tokens from the input stream and returns them to the parser. Bison does not create this function automatically; you must write it so that yyparse can call it. The function is sometimes referred to as a lexical scanner.

In simple programs, yylex is often defined at the end of the Bison grammar file. If yylex is defined in a separate source file, you need to arrange for the token-type macro definitions to be available there. To do this, use the ‘-d’ option when you run Bison, so that it will write these macro definitions into the separate parser header file, *name*.tab.h, which you can include in the other source files that need it. See [Chapter 9 [Invoking Bison], page 149](#_bookmark194).

#### Calling Convention for yylex

The value that yylex returns must be the positive numeric code for the type of token it has just found; a zero or negative value signifies end-of-input.

When a token is referred to in the grammar rules by a name, that name in the parser implementation file becomes a C macro whose definition is the proper numeric code for that token type. So yylex can use the name to indicate that type. See [Section 3.2 [Symbols],](#_bookmark52) [page 57](#_bookmark52).

When a token is referred to in the grammar rules by a character literal, the numeric code for that character is also the code for the token type. So yylex can simply return that character code, possibly converted to unsigned char to avoid sign-extension. The null character must not be used this way, because its code is zero and that signifies end-of-input.

Here is an example showing these things:

int

yylex (void)

{

...

if (c == EOF) /\* Detect end-of-input. \*/ return 0;

...

if (c == ’+’ || c == ’-’)

return c; /\* Assume token type for ’+’ is ’+’. \*/

...

return INT; /\* Return the type of the token. \*/

...

}

This interface has been designed so that the output from the lex utility can be used without change as the definition of yylex.

If the grammar uses literal string tokens, there are two ways that yylex can determine the token type codes for them:

If the grammar defines symbolic token names as aliases for the literal string tokens, yylex can use these symbolic names like all others. In this case, the use of the literal string tokens in the grammar file has no effect on yylex.

*•*

yylex can find the multicharacter token in the yytname table. The index of the token in the table is the token type’s code. The name of a multicharacter token is recorded in yytname with a double-quote, the token’s characters, and another double-quote. The token’s characters are escaped as necessary to be suitable as input to Bison.

*•*

Here’s code for looking up a multicharacter token in yytname, assuming that the char- acters of the token are stored in token\_buffer, and assuming that the token does not contain any characters like ‘"’ that require escaping.

for (i = 0; i < YYNTOKENS; i++)

{

if (yytname[i] != 0

&& yytname[i][0] == ’"’

&& ! strncmp (yytname[i] + 1, token\_buffer,

strlen (token\_buffer))

&& yytname[i][strlen (token\_buffer) + 1] == ’"’ && yytname[i][strlen (token\_buffer) + 2] == 0)

break;

}

The yytname table is generated only if you use the token-table declaration. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

#### Semantic Values of Tokens

In an ordinary (nonreentrant) parser, the semantic value of the token must be stored into the global variable yylval. When you are using just one data type for semantic values, yylval has that type. Thus, if the type is int (the default), you might write this in yylex:

...

yylval = value; /\* Put value onto Bison stack. \*/ return INT; /\* Return the type of the token. \*/

...

When you are using multiple data types, yylval’s type is a union made from the union declaration (see [Section 3.4.4 [The Union Declaration], page 63](#_bookmark66)). So when you store a token’s value, you must use the proper member of the union. If the union declaration looks like this:

union {

int intval; double val; symrec \*tptr;

}

then the code in yylex might look like this:

...

yylval.intval = value; /\* Put value onto Bison stack. \*/ return INT; /\* Return the type of the token. \*/

...

#### Textual Locations of Tokens

If you are using the ‘@*n*’-feature (see [Section 3.5 [Tracking Locations], page 71](#_bookmark79)) in actions to keep track of the textual locations of tokens and groupings, then you must provide this information in yylex. The function yyparse expects to find the textual location of a token just parsed in the global variable yylloc. So yylex must store the proper data in that variable.

By default, the value of yylloc is a structure and you need only initialize the members that are going to be used by the actions. The four members are called first\_line, first\_ column, last\_line and last\_column. Note that the use of this feature makes the parser noticeably slower.

The data type of yylloc has the name YYLTYPE.

#### Calling Conventions for Pure Parsers

When you use the Bison declaration define api.pure full to request a pure, reentrant parser, the global communication variables yylval and yylloc cannot be used. (See [Section 3.7.10 [A Pure (Reentrant) Parser], page 81](#_bookmark102).) In such parsers the two global vari- ables are replaced by pointers passed as arguments to yylex. You must declare them as shown here, and pass the information back by storing it through those pointers.

int

yylex (YYSTYPE \*lvalp, YYLTYPE \*llocp)

{

...

\*lvalp = value; /\* Put value onto Bison stack. \*/ return INT; /\* Return the type of the token. \*/

...

}

If the grammar file does not use the ‘@’ constructs to refer to textual locations, then the type YYLTYPE will not be defined. In this case, omit the second argument; yylex will be called with only one argument.

If you wish to pass additional arguments to yylex, use lex-param just like parse-param (see [Section 4.1 [Parser Function], page 97](#_bookmark120)). To pass additional arguments to both yylex and yyparse, use param.

lex-param *{argument-declaration} . . .*

[Directive]

Specify that *argument-declaration* are additional yylex argument declarations. You

may pass one or more such declarations, which is equivalent to repeating lex-param.

param *{argument-declaration} . . .*

[Directive]

Specify that *argument-declaration* are additional yylex/yyparse argument

declaration. This is equivalent to ‘lex-param {*argument-declaration*} ...

parse-param {*argument-declaration*} ...’. You may pass one or more declarations, which is equivalent to repeating param.

For instance:

lex-param {scanner\_mode \*mode} parse-param {parser\_mode \*mode} param {environment\_type \*env}

results in the following signatures:

int yylex (scanner\_mode \*mode, environment\_type \*env); int yyparse (parser\_mode \*mode, environment\_type \*env);

If ‘define api.pure full’ is added:

int yylex (YYSTYPE \*lvalp, scanner\_mode \*mode, environment\_type \*env); int yyparse (parser\_mode \*mode, environment\_type \*env);

and finally, if both ‘define api.pure full’ and locations are used:

int yylex (YYSTYPE \*lvalp, YYLTYPE \*llocp, scanner\_mode \*mode, environment\_type \*env);

int yyparse (parser\_mode \*mode, environment\_type \*env);

## The Error Reporting Function yyerror

The Bison parser detects a *syntax error* (or *parse error*) whenever it reads a token which cannot satisfy any syntax rule. An action in the grammar can also explicitly proclaim an error, using the macro YYERROR (see [Section 4.8 [Special Features for Use in Actions],](#_bookmark136) [page 103](#_bookmark136)).

The Bison parser expects to report the error by calling an error reporting function named yyerror, which you must supply. It is called by yyparse whenever a syntax error is found, and it receives one argument. For a syntax error, the string is normally "syntax error".

If you invoke ‘define parse.error verbose’ in the Bison declarations section (see [Section 3.1.3 [The Bison Declarations Section], page 56](#_bookmark50)), then Bison provides a more verbose and specific error message string instead of just plain "syntax error". However, that message sometimes contains incorrect information if LAC is not enabled (see [Section 5.8.3](#_bookmark162) [[LAC], page 121](#_bookmark162)).

The parser can detect one other kind of error: memory exhaustion. This can happen when the input contains constructions that are very deeply nested. It isn’t likely you will encounter this, since the Bison parser normally extends its stack automatically up to a very large limit. But if memory is exhausted, yyparse calls yyerror in the usual fashion, except that the argument string is "memory exhausted".

In some cases diagnostics like "syntax error" are translated automatically from English to some other language before they are passed to yyerror. See [Section 4.9 [International-](#_bookmark139) [ization], page 105](#_bookmark139).

The following definition suffices in simple programs:

void

yyerror (char const \*s)

{

fprintf (stderr, "s\n", s);

}

After yyerror returns to yyparse, the latter will attempt error recovery if you have written suitable error recovery grammar rules (see [Chapter 6 [Error Recovery], page 127](#_bookmark170)). If recovery is impossible, yyparse will immediately return 1.

Obviously, in location tracking pure parsers, yyerror should have an access to the current location. With define api.pure, this is indeed the case for the GLR parsers, but not for the Yacc parser, for historical reasons, and this is the why define api.pure full should be prefered over define api.pure.

When locations  define api.pure full is used, yyerror has the following signature:

void yyerror (YYLTYPE \*locp, char const \*msg);

The prototypes are only indications of how the code produced by Bison uses yyerror. Bison-generated code always ignores the returned value, so yyerror can return any type, including void. Also, yyerror can be a variadic function; that is why the message is always passed last.

Traditionally yyerror returns an int that is always ignored, but this is purely for historical reasons, and void is preferable since it more accurately describes the return type for yyerror.

The variable yynerrs contains the number of syntax errors reported so far. Normally this variable is global; but if you request a pure parser (see [Section 3.7.10 [A Pure (Reentrant)](#_bookmark102) [Parser], page 81](#_bookmark102)) then it is a local variable which only the actions can access.

## Special Features for Use in Actions

Here is a table of Bison constructs, variables and macros that are useful in actions.

$$ [Variable]

Acts like a variable that contains the semantic value for the grouping made by the current rule. See [Section 3.4.6 [Actions], page 64](#_bookmark68).

$*n* [Variable]

Acts like a variable that contains the semantic value for the *n*th component of the current rule. See [Section 3.4.6 [Actions], page 64](#_bookmark68).

$<*typealt*>$ [Variable]

Like $$ but specifies alternative *typealt* in the union specified by the union decla- ration. See [Section 3.4.7 [Data Types of Values in Actions], page 65](#_bookmark70).

$<*typealt*>*n* [Variable]

Like $*n* but specifies alternative *typealt* in the union specified by the union decla- ration. See [Section 3.4.7 [Data Types of Values in Actions], page 65](#_bookmark70).

YYABORT ; [Macro]

Return immediately from yyparse, indicating failure. See [Section 4.1 [The Parser](#_bookmark120) [Function yyparse], page 97](#_bookmark120).

YYACCEPT ; [Macro]

Return immediately from yyparse, indicating success. See [Section 4.1 [The Parser](#_bookmark120) [Function yyparse], page 97](#_bookmark120).

YYBACKUP (*token, value*); [Macro]

Unshift a token. This macro is allowed only for rules that reduce a single value, and only when there is no lookahead token. It is also disallowed in GLR parsers. It installs a lookahead token with token type *token* and semantic value *value*; then it discards the value that was going to be reduced by this rule.

If the macro is used when it is not valid, such as when there is a lookahead token already, then it reports a syntax error with a message ‘cannot back up’ and performs ordinary error recovery.

In either case, the rest of the action is not executed.

###### YYEMPTY

Value stored in yychar when there is no lookahead token.

###### YYEOF

Value stored in yychar when the lookahead is the end of the input stream.

###### YYERROR ;

[Macro]

[Macro] [Macro]

Cause an immediate syntax error. This statement initiates error recovery just as if the parser itself had detected an error; however, it does not call yyerror, and does not print any message. If you want to print an error message, call yyerror explicitly before the ‘YYERROR;’ statement. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

YYRECOVERING [Macro]

The expression YYRECOVERING () yields 1 when the parser is recovering from a syntax error, and 0 otherwise. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

yychar [Variable]

Variable containing either the lookahead token, or YYEOF when the lookahead is the end of the input stream, or YYEMPTY when no lookahead has been performed so the next token is not yet known. Do not modify yychar in a deferred semantic action (see [Section 1.5.3 [GLR Semantic Actions], page 25](#_bookmark14)). See [Section 5.1 [Lookahead Tokens],](#_bookmark141) [page 107](#_bookmark141).

yyclearin ; [Macro]

Discard the current lookahead token. This is useful primarily in error rules. Do not invoke yyclearin in a deferred semantic action (see [Section 1.5.3 [GLR Semantic](#_bookmark14) [Actions], page 25](#_bookmark14)). See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

yyerrok ; [Macro]

Resume generating error messages immediately for subsequent syntax errors. This is useful primarily in error rules. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

yylloc [Variable]

Variable containing the lookahead token location when yychar is not set to YYEMPTY or YYEOF. Do not modify yylloc in a deferred semantic action (see [Section 1.5.3 [GLR](#_bookmark14) [Semantic Actions], page 25](#_bookmark14)). See [Section 3.5.2 [Actions and Locations], page 71](#_bookmark81).

yylval [Variable]

Variable containing the lookahead token semantic value when yychar is not set to YYEMPTY or YYEOF. Do not modify yylval in a deferred semantic action (see [Section 1.5.3 [GLR Semantic Actions], page 25](#_bookmark14)). See [Section 3.4.6 [Actions], page 64](#_bookmark68).

@$ [Value]

Acts like a structure variable containing information on the textual location of the grouping made by the current rule. See [Section 3.5 [Tracking Locations], page 71](#_bookmark79).

@*n* [Value]

Acts like a structure variable containing information on the textual location of the

*n*th component of the current rule. See [Section 3.5 [Tracking Locations], page 71](#_bookmark79).

## Parser Internationalization

A Bison-generated parser can print diagnostics, including error and tracing messages. By default, they appear in English. However, Bison also supports outputting diagnostics in the user’s native language. To make this work, the user should set the usual environment variables. See Section “The User’s View” in *GNU* gettext *utilities*. For example, the shell command ‘export LC\_ALL=fr\_CA.UTF-8’ might set the user’s locale to French Cana- dian using the UTF-8 encoding. The exact set of available locales depends on the user’s installation.

The maintainer of a package that uses a Bison-generated parser enables the internation- alization of the parser’s output through the following steps. Here we assume a package that uses GNU Autoconf and GNU Automake.

1. Into the directory containing the GNU Autoconf macros used by the package

—often called m4— copy the bison-i18n.m4 file installed by Bison under ‘share/aclocal/bison-i18n.m4’ in Bison’s installation directory. For example:

cp /usr/local/share/aclocal/bison-i18n.m4 m4/bison-i18n.m4

1. In the top-level configure.ac, after the AM\_GNU\_GETTEXT invocation, add an invocation of BISON\_I18N. This macro is defined in the file bison-i18n.m4 that you copied earlier. It causes ‘configure’ to find the value of the BISON\_LOCALEDIR variable, and it defines the source-language symbol YYENABLE\_NLS to enable translations in the Bison-generated parser.
2. In the main function of your program, designate the directory containing Bison’s runtime message catalog, through a call to ‘bindtextdomain’ with domain name ‘bison-runtime’. For example:

bindtextdomain ("bison-runtime", BISON\_LOCALEDIR);

Typically this appears after any other call bindtextdomain (PACKAGE, LOCALEDIR) that your package already has. Here we rely on ‘BISON\_LOCALEDIR’ to be defined as a string through the Makefile.

1. In the Makefile.am that controls the compilation of the main function, make ‘BISON\_LOCALEDIR’ available as a C preprocessor macro, either in ‘DEFS’ or in ‘AM\_CPPFLAGS’. For example:

DEFS = @DEFS@ -DBISON\_LOCALEDIR=’"$(BISON\_LOCALEDIR)"’

or:

AM\_CPPFLAGS = -DBISON\_LOCALEDIR=’"$(BISON\_LOCALEDIR)"’

1. Finally, invoke the command autoreconf to generate the build infrastructure.

# The Bison Parser Algorithm

As Bison reads tokens, it pushes them onto a stack along with their semantic values. The stack is called the *parser stack*. Pushing a token is traditionally called *shifting*.

For example, suppose the infix calculator has read ‘1 + 5 \*’, with a ‘3’ to come. The stack will have four elements, one for each token that was shifted.

But the stack does not always have an element for each token read. When the last *n* tokens and groupings shifted match the components of a grammar rule, they can be combined according to that rule. This is called *reduction*. Those tokens and groupings are replaced on the stack by a single grouping whose symbol is the result (left hand side) of that rule. Running the rule’s action is part of the process of reduction, because this is what computes the semantic value of the resulting grouping.

For example, if the infix calculator’s parser stack contains this:

1 + 5 \* 3

and the next input token is a newline character, then the last three elements can be reduced to 15 via the rule:

expr: expr ’\*’ expr;

Then the stack contains just these three elements:

1 + 15

At this point, another reduction can be made, resulting in the single value 16. Then the newline token can be shifted.

The parser tries, by shifts and reductions, to reduce the entire input down to a single grouping whose symbol is the grammar’s start-symbol (see [Section 1.1 [Languages and](#_bookmark4) [Context-Free Grammars], page 17](#_bookmark4)).

This kind of parser is known in the literature as a bottom-up parser.

## Lookahead Tokens

The Bison parser does *not* always reduce immediately as soon as the last *n* tokens and groupings match a rule. This is because such a simple strategy is inadequate to handle most languages. Instead, when a reduction is possible, the parser sometimes “looks ahead” at the next token in order to decide what to do.

When a token is read, it is not immediately shifted; first it becomes the *lookahead token*, which is not on the stack. Now the parser can perform one or more reductions of tokens and groupings on the stack, while the lookahead token remains off to the side. When no more reductions should take place, the lookahead token is shifted onto the stack. This does not mean that all possible reductions have been done; depending on the token type of the lookahead token, some rules may choose to delay their application.

Here is a simple case where lookahead is needed. These three rules define expressions which contain binary addition operators and postfix unary factorial operators (‘!’), and allow parentheses for grouping.

expr:

term ’+’ expr

| term

;

term:

’(’ expr ’)’

| term ’!’

| "number"

;

Suppose that the tokens ‘1 + 2’ have been read and shifted; what should be done? If the following token is ‘)’, then the first three tokens must be reduced to form an expr. This is the only valid course, because shifting the ‘)’ would produce a sequence of symbols term ’)’, and no rule allows this.

If the following token is ‘!’, then it must be shifted immediately so that ‘2 !’ can be reduced to make a term. If instead the parser were to reduce before shifting, ‘1 + 2’ would become an expr. It would then be impossible to shift the ‘!’ because doing so would produce on the stack the sequence of symbols expr ’!’. No rule allows that sequence.

The lookahead token is stored in the variable yychar. Its semantic value and location, if any, are stored in the variables yylval and yylloc. See [Section 4.8 [Special Features for](#_bookmark136) [Use in Actions], page 103](#_bookmark136).

## Shift/Reduce Conflicts

Suppose we are parsing a language which has if-then and if-then-else statements, with a pair of rules like this:

if\_stmt:

"if" expr "then" stmt

| "if" expr "then" stmt "else" stmt

;

Here "if", "then" and "else" are terminal symbols for specific keyword tokens.

When the "else" token is read and becomes the lookahead token, the contents of the stack (assuming the input is valid) are just right for reduction by the first rule. But it is also legitimate to shift the "else", because that would lead to eventual reduction by the second rule.

This situation, where either a shift or a reduction would be valid, is called a *shift/reduce conflict*. Bison is designed to resolve these conflicts by choosing to shift, unless otherwise directed by operator precedence declarations. To see the reason for this, let’s contrast it with the other alternative.

Since the parser prefers to shift the "else", the result is to attach the else-clause to the innermost if-statement, making these two inputs equivalent:

if x then if y then win; else lose;

if x then do; if y then win; else lose; end;

But if the parser chose to reduce when possible rather than shift, the result would be to attach the else-clause to the outermost if-statement, making these two inputs equivalent:

if x then if y then win; else lose;

if x then do; if y then win; end; else lose;

The conflict exists because the grammar as written is ambiguous: either parsing of the simple nested if-statement is legitimate. The established convention is that these ambiguities are resolved by attaching the else-clause to the innermost if-statement; this is what Bison accomplishes by choosing to shift rather than reduce. (It would ideally be cleaner to write an unambiguous grammar, but that is very hard to do in this case.) This particular ambiguity was first encountered in the specifications of Algol 60 and is called the “dangling else” ambiguity.

To avoid warnings from Bison about predictable, legitimate shift/reduce conflicts, you can use the expect *n* declaration. There will be no warning as long as the number of shift/reduce conflicts is exactly *n*, and Bison will report an error if there is a different number. See [Section 3.7.8 [Suppressing Conflict Warnings], page 80](#_bookmark100). However, we don’t recommend the use of expect (except ‘ expect 0’!), as an equal number of conflicts does not mean that they are the *same*. When possible, you should rather use precedence direc- tives to *fix* the conflicts explicitly (see [Section 5.3.6 [Using Precedence For Non Operators],](#_bookmark148) [page 112](#_bookmark148)).

The definition of if\_stmt above is solely to blame for the conflict, but the conflict does not actually appear without additional rules. Here is a complete Bison grammar file that actually manifests the conflict:



stmt:

expr

| if\_stmt

;

if\_stmt:

"if" expr "then" stmt

| "if" expr "then" stmt "else" stmt

;

expr:

"identifier"

;

## Operator Precedence

Another situation where shift/reduce conflicts appear is in arithmetic expressions. Here shifting is not always the preferred resolution; the Bison declarations for operator precedence allow you to specify when to shift and when to reduce.

#### When Precedence is Needed

Consider the following ambiguous grammar fragment (ambiguous because the input ‘1 - 2 \* 3’ can be parsed in two different ways):

expr:

expr ’-’ expr

| expr ’\*’ expr

| expr ’<’ expr

| ’(’ expr ’)’

...

;

Suppose the parser has seen the tokens ‘1’, ‘-’ and ‘2’; should it reduce them via the rule for the subtraction operator? It depends on the next token. Of course, if the next token is ‘)’, we must reduce; shifting is invalid because no single rule can reduce the token sequence ‘- 2 )’ or anything starting with that. But if the next token is ‘\*’ or ‘<’, we have a choice: either shifting or reduction would allow the parse to complete, but with different results.

To decide which one Bison should do, we must consider the results. If the next operator token *op* is shifted, then it must be reduced first in order to permit another opportunity to reduce the difference. The result is (in effect) ‘1 - (2 *op* 3)’. On the other hand, if the subtraction is reduced before shifting *op*, the result is ‘(1 - 2) *op* 3’. Clearly, then, the choice of shift or reduce should depend on the relative precedence of the operators ‘-’ and *op*: ‘\*’ should be shifted first, but not ‘<’.

What about input such as ‘1 - 2 - 5’; should this be ‘(1 - 2) - 5’ or should it be ‘1 - (2 - 5)’? For most operators we prefer the former, which is called *left association*. The latter alternative, *right association*, is desirable for assignment operators. The choice of left or right association is a matter of whether the parser chooses to shift or reduce when the stack contains ‘1 - 2’ and the lookahead token is ‘-’: shifting makes right-associativity.

#### Specifying Operator Precedence

Bison allows you to specify these choices with the operator precedence declarations left and right. Each such declaration contains a list of tokens, which are operators whose precedence and associativity is being declared. The left declaration makes all those operators left-associative and the right declaration makes them right-associative. A third alternative is nonassoc, which declares that it is a syntax error to find the same operator twice “in a row”. The last alternative, precedence, allows to define only precedence and no associativity at all. As a result, any associativity-related conflict that remains will be reported as an compile-time error. The directive nonassoc creates run-time error: using the operator in a associative way is a syntax error. The directive precedence creates compile-time errors: an operator *can* be involved in an associativity-related conflict, contrary to what expected the grammar author.

The relative precedence of different operators is controlled by the order in which they are declared. The first precedence/associativity declaration in the file declares the oper- ators whose precedence is lowest, the next such declaration declares the operators whose precedence is a little higher, and so on.

#### Specifying Precedence Only

Since POSIX Yacc defines only left, right, and nonassoc, which all defines precedence and associativity, little attention is paid to the fact that precedence cannot be defined without defining associativity. Yet, sometimes, when trying to solve a conflict, precedence

suffices. In such a case, using left, right, or nonassoc might hide future (associativity related) conflicts that would remain hidden.

The dangling else ambiguity (see [Section 5.2 [Shift/Reduce Conflicts], page 108](#_bookmark143)) can be solved explicitly. This shift/reduce conflicts occurs in the following situation, where the period denotes the current parsing state:

if *e1* then if *e2* then *s1* . else *s2*

The conflict involves the reduction of the rule ‘IF expr THEN stmt’, which precedence is by default that of its last token (THEN), and the shifting of the token ELSE. The usual disambiguation (attach the else to the closest if), shifting must be preferred, i.e., the precedence of ELSE must be higher than that of THEN. But neither is expected to be involved in an associativity related conflict, which can be specified as follows.

precedence THEN precedence ELSE

The unary-minus is another typical example where associativity is usually over-specified, see [Section 2.2 [Infix Notation Calculator - calc], page 37](#_bookmark30). The left directive is tradition- ally used to declare the precedence of NEG, which is more than needed since it also defines its associativity. While this is harmless in the traditional example, who knows how NEG might be used in future evolutions of the grammar. . .

#### Precedence Examples

In our example, we would want the following declarations:

left ’<’ left ’-’ left ’\*’

In a more complete example, which supports other operators as well, we would declare them in groups of equal precedence. For example, ’+’ is declared with ’-’:

left ’<’ ’>’ ’=’ "!=" "<=" ">="

left ’+’ ’-’

left ’\*’ ’/’

#### How Precedence Works

The first effect of the precedence declarations is to assign precedence levels to the terminal symbols declared. The second effect is to assign precedence levels to certain rules: each rule gets its precedence from the last terminal symbol mentioned in the components. (You can also specify explicitly the precedence of a rule. See [Section 5.4 [Context-Dependent](#_bookmark149) [Precedence], page 112](#_bookmark149).)

Finally, the resolution of conflicts works by comparing the precedence of the rule being considered with that of the lookahead token. If the token’s precedence is higher, the choice is to shift. If the rule’s precedence is higher, the choice is to reduce. If they have equal precedence, the choice is made based on the associativity of that precedence level. The verbose output file made by ‘-v’ (see [Chapter 9 [Invoking Bison], page 149](#_bookmark194)) says how each conflict was resolved.

Not all rules and not all tokens have precedence. If either the rule or the lookahead token has no precedence, then the default is to shift.

#### Using Precedence For Non Operators

Using properly precedence and associativity directives can help fixing shift/reduce conflicts that do not involve arithmetics-like operators. For instance, the “dangling else” problem (see [Section 5.2 [Shift/Reduce Conflicts], page 108](#_bookmark143)) can be solved elegantly in two different ways.

In the present case, the conflict is between the token "else" willing to be shifted, and the rule ‘if\_stmt: "if" expr "then" stmt’, asking for reduction. By default, the precedence of a rule is that of its last token, here "then", so the conflict will be solved appropriately by giving "else" a precedence higher than that of "then", for instance as follows:

precedence "then" precedence "else"

Alternatively, you may give both tokens the same precedence, in which case associativity is used to solve the conflict. To preserve the shift action, use right associativity:

right "then" "else"

Neither solution is perfect however. Since Bison does not provide, so far, “scoped” precedence, both force you to declare the precedence of these keywords with respect to the other operators your grammar. Therefore, instead of being warned about new conflicts you would be unaware of (e.g., a shift/reduce conflict due to ‘if test then 1 else 2 + 3’ being ambiguous: ‘if test then 1 else (2 + 3)’ or ‘(if test then 1 else 2) + 3’?), the conflict will be already “fixed”.

## Context-Dependent Precedence

Often the precedence of an operator depends on the context. This sounds outlandish at first, but it is really very common. For example, a minus sign typically has a very high precedence as a unary operator, and a somewhat lower precedence (lower than multiplication) as a binary operator.

The Bison precedence declarations can only be used once for a given token; so a token has only one precedence declared in this way. For context-dependent precedence, you need to use an additional mechanism: the prec modifier for rules.

The prec modifier declares the precedence of a particular rule by specifying a terminal symbol whose precedence should be used for that rule. It’s not necessary for that symbol to appear otherwise in the rule. The modifier’s syntax is:

prec *terminal-symbol*

and it is written after the components of the rule. Its effect is to assign the rule the precedence of *terminal-symbol*, overriding the precedence that would be deduced for it in the ordinary way. The altered rule precedence then affects how conflicts involving that rule are resolved (see [Section 5.3 [Operator Precedence], page 109](#_bookmark145)).

Here is how prec solves the problem of unary minus. First, declare a precedence for a fictitious terminal symbol named UMINUS. There are no tokens of this type, but the symbol serves to stand for its precedence:

...

left ’+’ ’-’ left ’\*’

left UMINUS

Now the precedence of UMINUS can be used in specific rules:

exp:

...

| exp ’-’ exp

...

| ’-’ exp prec UMINUS

## Parser States

The function yyparse is implemented using a finite-state machine. The values pushed on the parser stack are not simply token type codes; they represent the entire sequence of terminal and nonterminal symbols at or near the top of the stack. The current state collects all the information about previous input which is relevant to deciding what to do next.

Each time a lookahead token is read, the current parser state together with the type of lookahead token are looked up in a table. This table entry can say, “Shift the lookahead token.” In this case, it also specifies the new parser state, which is pushed onto the top of the parser stack. Or it can say, “Reduce using rule number *n*.” This means that a certain number of tokens or groupings are taken off the top of the stack, and replaced by one grouping. In other words, that number of states are popped from the stack, and one new state is pushed.

There is one other alternative: the table can say that the lookahead token is erroneous in the current state. This causes error processing to begin (see [Chapter 6 [Error Recovery],](#_bookmark170) [page 127](#_bookmark170)).

## Reduce/Reduce Conflicts

A reduce/reduce conflict occurs if there are two or more rules that apply to the same sequence of input. This usually indicates a serious error in the grammar.

For example, here is an erroneous attempt to define a sequence of zero or more word

groupings.

sequence:

empty { printf ("empty sequence\n"); }

| maybeword

| sequence word { printf ("added word s\n", $2); }

;

maybeword:

empty { printf ("empty maybeword\n"); }

| word { printf ("single word s\n", $1); }

;

The error is an ambiguity: there is more than one way to parse a single word into a sequence. It could be reduced to a maybeword and then into a sequence via the second rule. Alternatively, nothing-at-all could be reduced into a sequence via the first rule, and this could be combined with the word using the third rule for sequence.

There is also more than one way to reduce nothing-at-all into a sequence. This can be done directly via the first rule, or indirectly via maybeword and then the second rule.

You might think that this is a distinction without a difference, because it does not change whether any particular input is valid or not. But it does affect which actions are run. One parsing order runs the second rule’s action; the other runs the first rule’s action and the third rule’s action. In this example, the output of the program changes.

Bison resolves a reduce/reduce conflict by choosing to use the rule that appears first in the grammar, but it is very risky to rely on this. Every reduce/reduce conflict must be studied and usually eliminated. Here is the proper way to define sequence:

sequence:

empty { printf ("empty sequence\n"); }

| sequence word { printf ("added word s\n", $2); }

;

Here is another common error that yields a reduce/reduce conflict:

sequence:

empty

| sequence words

| sequence redirects

;

words:

empty

| words word

;

redirects: empty

| redirects redirect

;

The intention here is to define a sequence which can contain either word or redirect groupings. The individual definitions of sequence, words and redirects are error-free, but the three together make a subtle ambiguity: even an empty input can be parsed in infinitely many ways!

Consider: nothing-at-all could be a words. Or it could be two words in a row, or three, or any number. It could equally well be a redirects, or two, or any number. Or it could be a words followed by three redirects and another words. And so on.

Here are two ways to correct these rules. First, to make it a single level of sequence:

sequence:

empty

| sequence word

| sequence redirect

;

Second, to prevent either a words or a redirects from being empty:

sequence:

empty

| sequence words

| sequence redirects

;

words:

word

| words word

;

redirects: redirect

| redirects redirect

;

Yet this proposal introduces another kind of ambiguity! The input ‘word word’ can be parsed as a single words composed of two ‘word’s, or as two one-word words (and likewise for redirect/redirects). However this ambiguity is now a shift/reduce conflict, and therefore it can now be addressed with precedence directives.

To simplify the matter, we will proceed with word and redirect being tokens: "word"

and "redirect".

To prefer the longest words, the conflict between the token "word" and the rule ‘sequence: sequence words’ must be resolved as a shift. To this end, we use the same techniques as exposed above, see [Section 5.3.6 [Using Precedence For Non Operators],](#_bookmark148) [page 112](#_bookmark148). One solution relies on precedences: use prec to give a lower precedence to the rule:

precedence "word" precedence "sequence"



sequence:

empty

| sequence word prec "sequence"

| sequence redirect prec "sequence"

;

words:

word

| words "word"

;

Another solution relies on associativity: provide both the token and the rule with the same precedence, but make them right-associative:

right "word" "redirect"



sequence:

empty

| sequence word prec "word"

| sequence redirect prec "redirect"

;

## Mysterious Conflicts

Sometimes reduce/reduce conflicts can occur that don’t look warranted. Here is an example:



def: param\_spec return\_spec ’,’; param\_spec:

type

| name\_list ’:’ type

;

return\_spec: type

| name ’:’ type

;

type: "id";

name: "id"; name\_list:

name

| name ’,’ name\_list

;

It would seem that this grammar can be parsed with only a single token of lookahead: when a param\_spec is being read, an "id" is a name if a comma or colon follows, or a type if another "id" follows. In other words, this grammar is LR(1).

However, for historical reasons, Bison cannot by default handle all LR(1) grammars. In this grammar, two contexts, that after an "id" at the beginning of a param\_spec and likewise at the beginning of a return\_spec, are similar enough that Bison assumes they are the same. They appear similar because the same set of rules would be active—the rule for reducing to a name and that for reducing to a type. Bison is unable to determine at that stage of processing that the rules would require different lookahead tokens in the two contexts, so it makes a single parser state for them both. Combining the two contexts causes a conflict later. In parser terminology, this occurrence means that the grammar is not LALR(1).

For many practical grammars (specifically those that fall into the non-LR(1) class), the limitations of LALR(1) result in difficulties beyond just mysterious reduce/reduce conflicts. The best way to fix all these problems is to select a different parser table construction algo- rithm. Either IELR(1) or canonical LR(1) would suffice, but the former is more efficient and easier to debug during development. See [Section 5.8.1 [LR Table Construction], page 118](#_bookmark157),

for details. (Bison’s IELR(1) and canonical LR(1) implementations are experimental. More user feedback will help to stabilize them.)

If you instead wish to work around LALR(1)’s limitations, you can often fix a mysterious conflict by identifying the two parser states that are being confused, and adding something to make them look distinct. In the above example, adding one rule to return\_spec as follows makes the problem go away:

...

return\_spec: type

| name ’:’ type

| "id" "bogus" /\* This rule is never used. \*/

;

This corrects the problem because it introduces the possibility of an additional active rule in the context after the "id" at the beginning of return\_spec. This rule is not active in the corresponding context in a param\_spec, so the two contexts receive distinct parser states. As long as the token "bogus" is never generated by yylex, the added rule cannot alter the way actual input is parsed.

In this particular example, there is another way to solve the problem: rewrite the rule for return\_spec to use "id" directly instead of via name. This also causes the two confusing contexts to have different sets of active rules, because the one for return\_spec activates the altered rule for return\_spec rather than the one for name.

param\_spec: type

| name\_list ’:’ type

;

return\_spec: type

| "id" ’:’ type

;

For a more detailed exposition of LALR(1) parsers and parser generators, see [[DeRemer](#_bookmark252) [1982], page 209](#_bookmark252).

## Tuning LR

The default behavior of Bison’s LR-based parsers is chosen mostly for historical reasons, but that behavior is often not robust. For example, in the previous section, we discussed the mysterious conflicts that can be produced by LALR(1), Bison’s default parser table construction algorithm. Another example is Bison’s define parse.error verbose direc- tive, which instructs the generated parser to produce verbose syntax error messages, which can sometimes contain incorrect information.

In this section, we explore several modern features of Bison that allow you to tune fun- damental aspects of the generated LR-based parsers. Some of these features easily eliminate shortcomings like those mentioned above. Others can be helpful purely for understanding your parser.

Most of the features discussed in this section are still experimental. More user feedback will help to stabilize them.

#### LR Table Construction

For historical reasons, Bison constructs LALR(1) parser tables by default. However, LALR does not possess the full language-recognition power of LR. As a result, the behavior of parsers employing LALR parser tables is often mysterious. We presented a simple example of this effect in [Section 5.7 [Mysterious Conflicts], page 116](#_bookmark154).

As we also demonstrated in that example, the traditional approach to eliminating such mysterious behavior is to restructure the grammar. Unfortunately, doing so correctly is often difficult. Moreover, merely discovering that LALR causes mysterious behavior in your parser can be difficult as well.

Fortunately, Bison provides an easy way to eliminate the possibility of such mysterious behavior altogether. You simply need to activate a more powerful parser table construction algorithm by using the define lr.type directive.

define lr.type *type* [Directive]

Specify the type of parser tables within the LR(1) family. The accepted values for

*type* are:

* + - * lalr (default)
      * ielr
      * canonical-lr

For example, to activate IELR, you might add the following directive to you grammar file:

define lr.type ielr

For the example in [Section 5.7 [Mysterious Conflicts], page 116](#_bookmark154), the mysterious conflict is then eliminated, so there is no need to invest time in comprehending the conflict or restructuring the grammar to fix it. If, during future development, the grammar evolves such that all mysterious behavior would have disappeared using just LALR, you need not fear that continuing to use IELR will result in unnecessarily large parser tables. That is, IELR generates LALR tables when LALR (using a deterministic parsing algorithm) is sufficient to support the full language-recognition power of LR. Thus, by enabling IELR at the start of grammar development, you can safely and completely eliminate the need to consider LALR’s shortcomings.

While IELR is almost always preferable, there are circumstances where LALR or the canonical LR parser tables described by Knuth (see [[Knuth 1965], page 209](#_bookmark252)) can be useful. Here we summarize the relative advantages of each parser table construction algorithm within Bison:

* LALR

There are at least two scenarios where LALR can be worthwhile:

* + GLR without static conflict resolution.

When employing GLR parsers (see [Section 1.5 [GLR Parsers], page 20](#_bookmark9)), if you do not resolve any conflicts statically (for example, with left or precedence), then the parser explores all potential parses of any given input. In this case, the choice

of parser table construction algorithm is guaranteed not to alter the language accepted by the parser. LALR parser tables are the smallest parser tables Bison can currently construct, so they may then be preferable. Nevertheless, once you begin to resolve conflicts statically, GLR behaves more like a deterministic parser in the syntactic contexts where those conflicts appear, and so either IELR or canonical LR can then be helpful to avoid LALR’s mysterious behavior.

* + Malformed grammars.

Occasionally during development, an especially malformed grammar with a major recurring flaw may severely impede the IELR or canonical LR parser table con- struction algorithm. LALR can be a quick way to construct parser tables in order to investigate such problems while ignoring the more subtle differences from IELR and canonical LR.

* IELR

IELR (Inadequacy Elimination LR) is a minimal LR algorithm. That is, given any grammar (LR or non-LR), parsers using IELR or canonical LR parser tables always accept exactly the same set of sentences. However, like LALR, IELR merges parser states during parser table construction so that the number of parser states is often an order of magnitude less than for canonical LR. More importantly, because canonical LR’s extra parser states may contain duplicate conflicts in the case of non-LR gram- mars, the number of conflicts for IELR is often an order of magnitude less as well. This effect can significantly reduce the complexity of developing a grammar.

* Canonical LR

While inefficient, canonical LR parser tables can be an interesting means to explore a grammar because they possess a property that IELR and LALR tables do not. That is, if nonassoc is not used and default reductions are left disabled (see [Section 5.8.2](#_bookmark159) [[Default Reductions], page 119](#_bookmark159)), then, for every left context of every canonical LR state, the set of tokens accepted by that state is guaranteed to be the exact set of tokens that is syntactically acceptable in that left context. It might then seem that an advantage of canonical LR parsers in production is that, under the above constraints, they are guaranteed to detect a syntax error as soon as possible without performing any unnecessary reductions. However, IELR parsers that use LAC are also able to achieve this behavior without sacrificing nonassoc or default reductions. For details and a few caveats of LAC, see [Section 5.8.3 [LAC], page 121](#_bookmark162).

For a more detailed exposition of the mysterious behavior in LALR parsers and the benefits of IELR, see [[Denny 2008 March], page 209](#_bookmark252), and [[Denny 2010 November], page 209](#_bookmark252).

#### Default Reductions

After parser table construction, Bison identifies the reduction with the largest lookahead set in each parser state. To reduce the size of the parser state, traditional Bison behavior is to remove that lookahead set and to assign that reduction to be the default parser action. Such a reduction is known as a *default reduction*.

Default reductions affect more than the size of the parser tables. They also affect the behavior of the parser:

* + - * Delayed yylex invocations.

A *consistent state* is a state that has only one possible parser action. If that action is a reduction and is encoded as a default reduction, then that consistent state is called a *defaulted state*. Upon reaching a defaulted state, a Bison-generated parser does not bother to invoke yylex to fetch the next token before performing the reduction. In other words, whether default reductions are enabled in consistent states determines how soon a Bison-generated parser invokes yylex for a token: immediately when it *reaches* that token in the input or when it eventually *needs* that token as a lookahead to determine the next parser action. Traditionally, default reductions are enabled, and so the parser exhibits the latter behavior.

The presence of defaulted states is an important consideration when designing yylex and the grammar file. That is, if the behavior of yylex can influence or be influenced by the semantic actions associated with the reductions in defaulted states, then the delay of the next yylex invocation until after those reductions is significant. For example, the semantic actions might pop a scope stack that yylex uses to determine what token to return. Thus, the delay might be necessary to ensure that yylex does not look up the next token in a scope that should already be considered closed.

* + - * Delayed syntax error detection.

When the parser fetches a new token by invoking yylex, it checks whether there is an action for that token in the current parser state. The parser detects a syntax error if and only if either (1) there is no action for that token or (2) the action for that token is the error action (due to the use of nonassoc). However, if there is a default reduction in that state (which might or might not be a defaulted state), then it is impossible for condition 1 to exist. That is, all tokens have an action. Thus, the parser sometimes fails to detect the syntax error until it reaches a later state.

While default reductions never cause the parser to accept syntactically incorrect sen- tences, the delay of syntax error detection can have unexpected effects on the behavior of the parser. However, the delay can be caused anyway by parser state merging and the use of nonassoc, and it can be fixed by another Bison feature, LAC. We discuss the effects of delayed syntax error detection and LAC more in the next section (see [Section 5.8.3 [LAC], page 121](#_bookmark162)).

For canonical LR, the only default reduction that Bison enables by default is the accept action, which appears only in the accepting state, which has no other action and is thus a defaulted state. However, the default accept action does not delay any yylex invocation or syntax error detection because the accept action ends the parse.

For LALR and IELR, Bison enables default reductions in nearly all states by default. There are only two exceptions. First, states that have a shift action on the error token do not have default reductions because delayed syntax error detection could then prevent the error token from ever being shifted in that state. However, parser state merging can cause the same effect anyway, and LAC fixes it in both cases, so future versions of Bison might drop this exception when LAC is activated. Second, GLR parsers do not record the default reduction as the action on a lookahead token for which there is a conflict. The correct action in this case is to split the parse instead.

To adjust which states have default reductions enabled, use the define lr.default-reduction directive.

define lr.default-reduction *where* [Directive]

Specify the kind of states that are permitted to contain default reductions. The accepted values of *where* are:

* + - * + most (default for LALR and IELR)
        + consistent
        + accepting (default for canonical LR)

(The ability to specify where default reductions are permitted is experimental. More user feedback will help to stabilize it.)

#### LAC

Canonical LR, IELR, and LALR can suffer from a couple of problems upon encountering a syntax error. First, the parser might perform additional parser stack reductions before discovering the syntax error. Such reductions can perform user semantic actions that are unexpected because they are based on an invalid token, and they cause error recovery to begin in a different syntactic context than the one in which the invalid token was encoun- tered. Second, when verbose error messages are enabled (see [Section 4.7 [Error Reporting],](#_bookmark134) [page 102](#_bookmark134)), the expected token list in the syntax error message can both contain invalid tokens and omit valid tokens.

The culprits for the above problems are nonassoc, default reductions in inconsistent states (see [Section 5.8.2 [Default Reductions], page 119](#_bookmark159)), and parser state merging. Because IELR and LALR merge parser states, they suffer the most. Canonical LR can suffer only if nonassoc is used or if default reductions are enabled for inconsistent states.

LAC (Lookahead Correction) is a new mechanism within the parsing algorithm that solves these problems for canonical LR, IELR, and LALR without sacrificing nonassoc, default reductions, or state merging. You can enable LAC with the define parse.lac directive.

define parse.lac *value*

Enable LAC to improve syntax error handling.

* + - * none (default)
      * full

[Directive]

(This feature is experimental. More user feedback will help to stabilize it. Moreover, it is currently only available for deterministic parsers in C.)

Conceptually, the LAC mechanism is straight-forward. Whenever the parser fetches a new token from the scanner so that it can determine the next parser action, it immediately suspends normal parsing and performs an exploratory parse using a temporary copy of the normal parser state stack. During this exploratory parse, the parser does not perform user semantic actions. If the exploratory parse reaches a shift action, normal parsing then resumes on the normal parser stacks. If the exploratory parse reaches an error instead, the parser reports a syntax error. If verbose syntax error messages are enabled, the parser must then discover the list of expected tokens, so it performs a separate exploratory parse for each token in the grammar.

There is one subtlety about the use of LAC. That is, when in a consistent parser state with a default reduction, the parser will not attempt to fetch a token from the scanner

because no lookahead is needed to determine the next parser action. Thus, whether default reductions are enabled in consistent states (see [Section 5.8.2 [Default Reductions], page 119](#_bookmark159)) affects how soon the parser detects a syntax error: immediately when it *reaches* an erroneous token or when it eventually *needs* that token as a lookahead to determine the next parser action. The latter behavior is probably more intuitive, so Bison currently provides no way to achieve the former behavior while default reductions are enabled in consistent states.

Thus, when LAC is in use, for some fixed decision of whether to enable default reductions in consistent states, canonical LR and IELR behave almost exactly the same for both syntactically acceptable and syntactically unacceptable input. While LALR still does not support the full language-recognition power of canonical LR and IELR, LAC at least enables LALR’s syntax error handling to correctly reflect LALR’s language-recognition power.

There are a few caveats to consider when using LAC:

* Infinite parsing loops.

IELR plus LAC does have one shortcoming relative to canonical LR. Some parsers generated by Bison can loop infinitely. LAC does not fix infinite parsing loops that occur between encountering a syntax error and detecting it, but enabling canonical LR or disabling default reductions sometimes does.

* Verbose error message limitations.

Because of internationalization considerations, Bison-generated parsers limit the size of the expected token list they are willing to report in a verbose syntax error message. If the number of expected tokens exceeds that limit, the list is simply dropped from the message. Enabling LAC can increase the size of the list and thus cause the parser to drop it. Of course, dropping the list is better than reporting an incorrect list.

* Performance.

Because LAC requires many parse actions to be performed twice, it can have a perfor- mance penalty. However, not all parse actions must be performed twice. Specifically, during a series of default reductions in consistent states and shift actions, the parser never has to initiate an exploratory parse. Moreover, the most time-consuming tasks in a parse are often the file I/O, the lexical analysis performed by the scanner, and the user’s semantic actions, but none of these are performed during the exploratory parse. Finally, the base of the temporary stack used during an exploratory parse is a pointer into the normal parser state stack so that the stack is never physically copied. In our experience, the performance penalty of LAC has proved insignificant for practical grammars.

While the LAC algorithm shares techniques that have been recognized in the parser community for years, for the publication that introduces LAC, see [[Denny 2010 May],](#_bookmark252) [page 209](#_bookmark252).

#### Unreachable States

If there exists no sequence of transitions from the parser’s start state to some state *s*, then Bison considers *s* to be an *unreachable state*. A state can become unreachable during conflict resolution if Bison disables a shift action leading to it from a predecessor state.

By default, Bison removes unreachable states from the parser after conflict resolution because they are useless in the generated parser. However, keeping unreachable states is

sometimes useful when trying to understand the relationship between the parser and the grammar.

define lr.keep-unreachable-state *value* [Directive]

Request that Bison allow unreachable states to remain in the parser tables. *value*

must be a Boolean. The default is false.

There are a few caveats to consider:

* + - * Missing or extraneous warnings.

Unreachable states may contain conflicts and may use rules not used in any other state. Thus, keeping unreachable states may induce warnings that are irrelevant to your parser’s behavior, and it may eliminate warnings that are relevant. Of course, the change in warnings may actually be relevant to a parser table analysis that wants to keep unreachable states, so this behavior will likely remain in future Bison releases.

* + - * Other useless states.

While Bison is able to remove unreachable states, it is not guaranteed to remove other kinds of useless states. Specifically, when Bison disables reduce actions during conflict resolution, some goto actions may become useless, and thus some additional states may become useless. If Bison were to compute which goto actions were useless and then disable those actions, it could identify such states as unreachable and then remove those states. However, Bison does not compute which goto actions are useless.

## Generalized LR (GLR) Parsing

Bison produces *deterministic* parsers that choose uniquely when to reduce and which re- duction to apply based on a summary of the preceding input and on one extra token of lookahead. As a result, normal Bison handles a proper subset of the family of context- free languages. Ambiguous grammars, since they have strings with more than one possible sequence of reductions cannot have deterministic parsers in this sense. The same is true of languages that require more than one symbol of lookahead, since the parser lacks the information necessary to make a decision at the point it must be made in a shift-reduce parser. Finally, as previously mentioned (see [Section 5.7 [Mysterious Conflicts], page 116](#_bookmark154)), there are languages where Bison’s default choice of how to summarize the input seen so far loses necessary information.

When you use the ‘glr-parser’ declaration in your grammar file, Bison generates a parser that uses a different algorithm, called Generalized LR (or GLR). A Bison GLR parser uses the same basic algorithm for parsing as an ordinary Bison parser, but behaves differently in cases where there is a shift-reduce conflict that has not been resolved by precedence rules (see [Section 5.3 [Precedence], page 109](#_bookmark145)) or a reduce-reduce conflict. When a GLR parser encounters such a situation, it effectively *splits* into a several parsers, one for each possible shift or reduction. These parsers then proceed as usual, consuming tokens in lock-step. Some of the stacks may encounter other conflicts and split further, with the result that instead of a sequence of states, a Bison GLR parsing stack is what is in effect a tree of states.

In effect, each stack represents a guess as to what the proper parse is. Additional input may indicate that a guess was wrong, in which case the appropriate stack silently disappears. Otherwise, the semantics actions generated in each stack are saved, rather than

being executed immediately. When a stack disappears, its saved semantic actions never get executed. When a reduction causes two stacks to become equivalent, their sets of semantic actions are both saved with the state that results from the reduction. We say that two stacks are equivalent when they both represent the same sequence of states, and each pair of corresponding states represents a grammar symbol that produces the same segment of the input token stream.

Whenever the parser makes a transition from having multiple states to having one, it reverts to the normal deterministic parsing algorithm, after resolving and executing the saved-up actions. At this transition, some of the states on the stack will have semantic values that are sets (actually multisets) of possible actions. The parser tries to pick one of the actions by first finding one whose rule has the highest dynamic precedence, as set by the ‘dprec’ declaration. Otherwise, if the alternative actions are not ordered by precedence, but there the same merging function is declared for both rules by the ‘merge’ declaration, Bison resolves and evaluates both and then calls the merge function on the result. Otherwise, it reports an ambiguity.

It is possible to use a data structure for the GLR parsing tree that permits the pro- cessing of any LR(1) grammar in linear time (in the size of the input), any unambiguous (not necessarily LR(1)) grammar in quadratic worst-case time, and any general (possibly ambiguous) context-free grammar in cubic worst-case time. However, Bison currently uses a simpler data structure that requires time proportional to the length of the input times the maximum number of stacks required for any prefix of the input. Thus, really ambiguous or nondeterministic grammars can require exponential time and space to process. Such badly behaving examples, however, are not generally of practical interest. Usually, nonde- terminism in a grammar is local—the parser is “in doubt” only for a few tokens at a time. Therefore, the current data structure should generally be adequate. On LR(1) portions of a grammar, in particular, it is only slightly slower than with the deterministic LR(1) Bison parser.

For a more detailed exposition of GLR parsers, see [[Scott 2000], page 209](#_bookmark252).

## Memory Management, and How to Avoid Memory Exhaustion

The Bison parser stack can run out of memory if too many tokens are shifted and not reduced. When this happens, the parser function yyparse calls yyerror and then returns 2.

Because Bison parsers have growing stacks, hitting the upper limit usually results from using a right recursion instead of a left recursion, see [Section 3.3.3 [Recursive Rules], page 60](#_bookmark58). By defining the macro YYMAXDEPTH, you can control how deep the parser stack can

become before memory is exhausted. Define the macro with a value that is an integer. This value is the maximum number of tokens that can be shifted (and not reduced) before overflow.

The stack space allowed is not necessarily allocated. If you specify a large value for YYMAXDEPTH, the parser normally allocates a small stack at first, and then makes it bigger by stages as needed. This increasing allocation happens automatically and silently. Therefore, you do not need to make YYMAXDEPTH painfully small merely to save space for ordinary inputs that do not need much stack.

However, do not allow YYMAXDEPTH to be a value so large that arithmetic overflow could occur when calculating the size of the stack space. Also, do not allow YYMAXDEPTH to be less than YYINITDEPTH.

The default value of YYMAXDEPTH, if you do not define it, is 10000.

You can control how much stack is allocated initially by defining the macro YYINITDEPTH to a positive integer. For the deterministic parser in C, this value must be a compile-time constant unless you are assuming C99 or some other target language or compiler that allows variable-length arrays. The default is 200.

Do not allow YYINITDEPTH to be greater than YYMAXDEPTH.

You can generate a deterministic parser containing C++ user code from the default

(C) skeleton, as well as from the C++ skeleton (see [Section 10.1 [C++ Parsers], page 157](#_bookmark199)). However, if you do use the default skeleton and want to allow the parsing stack to grow, be careful not to use semantic types or location types that require non-trivial copy constructors. The C skeleton bypasses these constructors when copying data to new, larger stacks.

# Error Recovery

It is not usually acceptable to have a program terminate on a syntax error. For example, a compiler should recover sufficiently to parse the rest of the input file and check it for errors; a calculator should accept another expression.

In a simple interactive command parser where each input is one line, it may be sufficient to allow yyparse to return 1 on error and have the caller ignore the rest of the input line when that happens (and then call yyparse again). But this is inadequate for a compiler, because it forgets all the syntactic context leading up to the error. A syntax error deep within a function in the compiler input should not cause the compiler to treat the following line like the beginning of a source file.

You can define how to recover from a syntax error by writing rules to recognize the special token error. This is a terminal symbol that is always defined (you need not declare it) and reserved for error handling. The Bison parser generates an error token whenever a syntax error happens; if you have provided a rule to recognize this token in the current context, the parse can continue.

For example:

stmts:

empty

| stmts ’\n’

| stmts exp ’\n’

| stmts error ’\n’

The fourth rule in this example says that an error followed by a newline makes a valid addition to any stmts.

What happens if a syntax error occurs in the middle of an exp? The error recovery rule, interpreted strictly, applies to the precise sequence of a stmts, an error and a newline. If an error occurs in the middle of an exp, there will probably be some additional tokens and subexpressions on the stack after the last stmts, and there will be tokens to read before the next newline. So the rule is not applicable in the ordinary way.

But Bison can force the situation to fit the rule, by discarding part of the semantic context and part of the input. First it discards states and objects from the stack until it gets back to a state in which the error token is acceptable. (This means that the subexpressions already parsed are discarded, back to the last complete stmts.) At this point the error token can be shifted. Then, if the old lookahead token is not acceptable to be shifted next, the parser reads tokens and discards them until it finds a token which is acceptable. In this example, Bison reads and discards input until the next newline so that the fourth rule can apply. Note that discarded symbols are possible sources of memory leaks, see [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95), for a means to reclaim this memory.

The choice of error rules in the grammar is a choice of strategies for error recovery. A simple and useful strategy is simply to skip the rest of the current input line or current statement if an error is detected:

stmt: error ’;’ /\* On error, skip until ’;’ is read. \*/

It is also useful to recover to the matching close-delimiter of an opening-delimiter that has already been parsed. Otherwise the close-delimiter will probably appear to be unmatched, and generate another, spurious error message:

primary:

’(’ expr ’)’

| ’(’ error ’)’

...

;

Error recovery strategies are necessarily guesses. When they guess wrong, one syntax error often leads to another. In the above example, the error recovery rule guesses that an error is due to bad input within one stmt. Suppose that instead a spurious semicolon is inserted in the middle of a valid stmt. After the error recovery rule recovers from the first error, another syntax error will be found straightaway, since the text following the spurious semicolon is also an invalid stmt.

To prevent an outpouring of error messages, the parser will output no error message for another syntax error that happens shortly after the first; only after three consecutive input tokens have been successfully shifted will error messages resume.

Note that rules which accept the error token may have actions, just as any other rules can.

You can make error messages resume immediately by using the macro yyerrok in an action. If you do this in the error rule’s action, no error messages will be suppressed. This macro requires no arguments; ‘yyerrok;’ is a valid C statement.

The previous lookahead token is reanalyzed immediately after an error. If this is unac- ceptable, then the macro yyclearin may be used to clear this token. Write the statement ‘yyclearin;’ in the error rule’s action. See [Section 4.8 [Special Features for Use in Actions],](#_bookmark136) [page 103](#_bookmark136).

For example, suppose that on a syntax error, an error handling routine is called that advances the input stream to some point where parsing should once again commence. The next symbol returned by the lexical scanner is probably correct. The previous lookahead token ought to be discarded with ‘yyclearin;’.

The expression YYRECOVERING () yields 1 when the parser is recovering from a syntax error, and 0 otherwise. Syntax error diagnostics are suppressed while recovering from a syntax error.

# Handling Context Dependencies

The Bison paradigm is to parse tokens first, then group them into larger syntactic units. In many languages, the meaning of a token is affected by its context. Although this violates the Bison paradigm, certain techniques (known as *kludges*) may enable you to write Bison parsers for such languages.

(Actually, “kludge” means any technique that gets its job done but is neither clean nor robust.)

## Semantic Info in Token Types

The C language has a context dependency: the way an identifier is used depends on what its current meaning is. For example, consider this:

foo (x);

This looks like a function call statement, but if foo is a typedef name, then this is actually a declaration of x. How can a Bison parser for C decide how to parse this input?

The method used in GNU C is to have two different token types, IDENTIFIER and TYPENAME. When yylex finds an identifier, it looks up the current declaration of the iden- tifier in order to decide which token type to return: TYPENAME if the identifier is declared as a typedef, IDENTIFIER otherwise.

The grammar rules can then express the context dependency by the choice of token type to recognize. IDENTIFIER is accepted as an expression, but TYPENAME is not. TYPENAME can start a declaration, but IDENTIFIER cannot. In contexts where the meaning of the identifier is *not* significant, such as in declarations that can shadow a typedef name, either TYPENAME or IDENTIFIER is accepted—there is one rule for each of the two token types.

This technique is simple to use if the decision of which kinds of identifiers to allow is made at a place close to where the identifier is parsed. But in C this is not always so: C allows a declaration to redeclare a typedef name provided an explicit type has been specified earlier:

typedef int foo, bar; int baz (void)

{

static bar (bar); /\* redeclare bar as static variable \*/ extern foo foo (foo); /\* redeclare foo as function \*/ return foo (bar);

}

Unfortunately, the name being declared is separated from the declaration construct itself by a complicated syntactic structure—the “declarator”.

As a result, part of the Bison parser for C needs to be duplicated, with all the nonterminal names changed: once for parsing a declaration in which a typedef name can be redefined, and once for parsing a declaration in which that can’t be done. Here is a part of the duplication, with actions omitted for brevity:

initdcl:

declarator maybeasm ’=’ init

| declarator maybeasm

;

notype\_initdcl:

notype\_declarator maybeasm ’=’ init

| notype\_declarator maybeasm

;

Here initdcl can redeclare a typedef name, but notype\_initdcl cannot. The distinction between declarator and notype\_declarator is the same sort of thing.

There is some similarity between this technique and a lexical tie-in (described next), in that information which alters the lexical analysis is changed during parsing by other parts of the program. The difference is here the information is global, and is used for other purposes in the program. A true lexical tie-in has a special-purpose flag controlled by the syntactic context.

## Lexical Tie-ins

One way to handle context-dependency is the *lexical tie-in*: a flag which is set by Bison actions, whose purpose is to alter the way tokens are parsed.

For example, suppose we have a language vaguely like C, but with a special construct ‘hex (*hex-expr*)’. After the keyword hex comes an expression in parentheses in which all integers are hexadecimal. In particular, the token ‘a1b’ must be treated as an integer rather than as an identifier if it appears in that context. Here is how you can do it:

{

int hexflag;

int yylex (void);

void yyerror (char const \*); }



...

expr:

IDENTIFIER

| constant

| HEX ’(’ { hexflag = 1; }

expr ’)’ { hexflag = 0; $$ = $4; }

| expr ’+’ expr { $$ = make\_sum ($1, $3); }

...

;

constant:

INTEGER

| STRING

;

Here we assume that yylex looks at the value of hexflag; when it is nonzero, all integers are parsed in hexadecimal, and tokens starting with letters are parsed as integers if possible.

The declaration of hexflag shown in the prologue of the grammar file is needed to make it accessible to the actions (see [Section 3.1.1 [The Prologue], page 51](#_bookmark46)). You must also write the code in yylex to obey the flag.

## Lexical Tie-ins and Error Recovery

Lexical tie-ins make strict demands on any error recovery rules you have. See [Chapter 6](#_bookmark170) [[Error Recovery], page 127](#_bookmark170).

The reason for this is that the purpose of an error recovery rule is to abort the parsing of one construct and resume in some larger construct. For example, in C-like languages, a typical error recovery rule is to skip tokens until the next semicolon, and then start a new statement, like this:

stmt:

expr ’;’

| IF ’(’ expr ’)’ stmt { ... }

...

| error ’;’ { hexflag = 0; }

;

If there is a syntax error in the middle of a ‘hex (*expr*)’ construct, this error rule will apply, and then the action for the completed ‘hex (*expr*)’ will never run. So hexflag would remain set for the entire rest of the input, or until the next hex keyword, causing identifiers to be misinterpreted as integers.

To avoid this problem the error recovery rule itself clears hexflag.

There may also be an error recovery rule that works within expressions. For example, there could be a rule which applies within parentheses and skips to the close-parenthesis:

expr:

...

| ’(’ expr ’)’ { $$ = $2; }

| ’(’ error ’)’

...

If this rule acts within the hex construct, it is not going to abort that construct (since it applies to an inner level of parentheses within the construct). Therefore, it should not clear the flag: the rest of the hex construct should be parsed with the flag still in effect.

What if there is an error recovery rule which might abort out of the hex construct or might not, depending on circumstances? There is no way you can write the action to determine whether a hex construct is being aborted or not. So if you are using a lexical tie-in, you had better make sure your error recovery rules are not of this kind. Each rule must be such that you can be sure that it always will, or always won’t, have to clear the flag.

# Debugging Your Parser

Developing a parser can be a challenge, especially if you don’t understand the algorithm (see [Chapter 5 [The Bison Parser Algorithm], page 107](#_bookmark140)). This chapter explains how to understand and debug a parser.

The first sections focus on the static part of the parser: its structure. They explain how to generate and read the detailed description of the automaton. There are several formats available:

* as text, see [Section 8.1 [Understanding Your Parser], page 133](#_bookmark178);
* as a graph, see [Section 8.2 [Visualizing Your Parser], page 140](#_bookmark183);

or as a markup report that can be turned, for instance, into HTML, see [Section 8.3](#_bookmark186) [[Visualizing your parser in multiple formats], page 142](#_bookmark186).

*−*

The last section focuses on the dynamic part of the parser: how to enable and understand the parser run-time traces (see [Section 8.4 [Tracing Your Parser], page 143](#_bookmark188)).

## Understanding Your Parser

As documented elsewhere (see [Chapter 5 [The Bison Parser Algorithm], page 107](#_bookmark140)) Bison parsers are *shift/reduce automata*. In some cases (much more frequent than one would hope), looking at this automaton is required to tune or simply fix a parser.

The textual file is generated when the options --report or --verbose are specified, see [Chapter 9 [Invoking Bison], page 149](#_bookmark194). Its name is made by removing ‘.tab.c’ or ‘.c’ from the parser implementation file name, and adding ‘.output’ instead. Therefore, if the grammar file is foo.y, then the parser implementation file is called foo.tab.c by default. As a consequence, the verbose output file is called foo.output.

The following grammar file, calc.y, will be used in the sequel:

union

{

int ival;

const char \*sval;

}

token <ival> NUM nterm <ival> exp token <sval> STR nterm <sval> useless left ’+’ ’-’

left ’\*’



exp:

exp ’+’ exp

| exp ’-’ exp

| exp ’\*’ exp

| exp ’/’ exp

| NUM

;

useless: STR;



bison reports:

calc.y: warning: 1 nonterminal useless in grammar [-Wother] calc.y: warning: 1 rule useless in grammar [-Wother]

calc.y:19.1-7: warning: nonterminal useless in grammar: useless [-Wother] useless: STR;

^^^^^^^

calc.y: warning: 7 shift/reduce conflicts [-Wconflicts-sr]

When given --report=state, in addition to calc.tab.c, it creates a file calc.output with contents detailed below. The order of the output and the exact presentation might vary, but the interpretation is the same.

The first section reports useless tokens, nonterminals and rules. Useless nonterminals and rules are removed in order to produce a smaller parser, but useless tokens are preserved, since they might be used by the scanner (note the difference between “useless” and “unused” below):

Nonterminals useless in grammar useless

Terminals unused in grammar STR

Rules useless in grammar

6 useless: STR

The next section lists states that still have conflicts.

State 8 conflicts: 1 shift/reduce

State 9 conflicts: 1 shift/reduce

State 10 conflicts: 1 shift/reduce

State 11 conflicts: 4 shift/reduce

Then Bison reproduces the exact grammar it used:

Grammar

1. $accept: exp $end
2. exp: exp ’+’ exp
3. | exp ’-’ exp
4. | exp ’\*’ exp
5. | exp ’/’ exp
6. | NUM

and reports the uses of the symbols:

Terminals, with rules where they appear

$end (0) 0

’\*’ (42) 3

’+’ (43) 1

’-’ (45) 2

’/’ (47) 4

error (256)

NUM <ival> (258) 5

STR <sval> (259)

Nonterminals, with rules where they appear

$accept (9)

on left: 0

exp <ival> (10)

on left: 1 2 3 4 5, on right: 0 1 2 3 4

Bison then proceeds onto the automaton itself, describing each state with its set of *items*, also known as *pointed rules*. Each item is a production rule together with a point (‘.’) marking the location of the input cursor.

State 0

0 $accept: . exp $end

NUM shift, and go to state 1 exp go to state 2

This reads as follows: “state 0 corresponds to being at the very beginning of the parsing, in the initial rule, right before the start symbol (here, exp). When the parser returns to this state right after having reduced a rule that produced an exp, the control flow jumps to state 2. If there is no such transition on a nonterminal symbol, and the lookahead is a NUM, then this token is shifted onto the parse stack, and the control flow jumps to state 1. Any other lookahead triggers a syntax error.”

Even though the only active rule in state 0 seems to be rule 0, the report lists NUM as a lookahead token because NUM can be at the beginning of any rule deriving an exp. By default Bison reports the so-called *core* or *kernel* of the item set, but if you want to see more detail you can invoke bison with --report=itemset to list the derived items as well:

State 0

1. $accept: . exp $end
2. exp: . exp ’+’ exp
3. | . exp ’-’ exp
4. | . exp ’\*’ exp
5. | . exp ’/’ exp
6. | . NUM

NUM shift, and go to state 1

exp go to state 2

In the state 1. . .

State 1

5 exp: NUM .

$default reduce using rule 5 (exp)

the rule 5, ‘exp: NUM;’, is completed. Whatever the lookahead token (‘$default’), the parser will reduce it. If it was coming from State 0, then, after this reduction it will return to state 0, and will jump to state 2 (‘exp: go to state 2’).

State 2

1. $accept: exp . $end
2. exp: exp . ’+’ exp
3. | exp . ’-’ exp
4. | exp . ’\*’ exp
5. | exp . ’/’ exp

$end shift, and go to state 3 ’+’ shift, and go to state 4 ’-’ shift, and go to state 5 ’\*’ shift, and go to state 6 ’/’ shift, and go to state 7

In state 2, the automaton can only shift a symbol. For instance, because of the item ‘exp: exp . ’+’ exp’, if the lookahead is ‘+’ it is shifted onto the parse stack, and the automaton jumps to state 4, corresponding to the item ‘exp: exp ’+’ . exp’. Since there is no default action, any lookahead not listed triggers a syntax error.

The state 3 is named the *final state*, or the *accepting state*:

State 3

1. $accept: exp $end .

$default accept

the initial rule is completed (the start symbol and the end-of-input were read), the parsing exits successfully.

The interpretation of states 4 to 7 is straightforward, and is left to the reader.

State 4

1. exp: exp ’+’ . exp

NUM shift, and go to state 1 exp go to state 8

State 5

1. exp: exp ’-’ . exp

NUM shift, and go to state 1 exp go to state 9

State 6

1. exp: exp ’\*’ . exp

NUM shift, and go to state 1 exp go to state 10

State 7

1. exp: exp ’/’ . exp

NUM shift, and go to state 1 exp go to state 11

As was announced in beginning of the report, ‘State 8 conflicts: 1 shift/reduce’: State 8

1 exp: exp . ’+’ exp

1. | exp ’+’ exp .
2. | exp . ’-’ exp
3. | exp . ’\*’ exp
4. | exp . ’/’ exp

’\*’ shift, and go to state 6 ’/’ shift, and go to state 7

’/’ [reduce using rule 1 (exp)]

$default reduce using rule 1 (exp)

Indeed, there are two actions associated to the lookahead ‘/’: either shifting (and going to state 7), or reducing rule 1. The conflict means that either the grammar is ambiguous, or the parser lacks information to make the right decision. Indeed the grammar is ambiguous, as, since we did not specify the precedence of ‘/’, the sentence ‘NUM + NUM / NUM’ can be

parsed as ‘NUM + (NUM / NUM)’, which corresponds to shifting ‘/’, or as ‘(NUM + NUM) / NUM’, which corresponds to reducing rule 1.

Because in deterministic parsing a single decision can be made, Bison arbitrarily chose to disable the reduction, see [Section 5.2 [Shift/Reduce Conflicts], page 108](#_bookmark143). Discarded actions are reported between square brackets.

Note that all the previous states had a single possible action: either shifting the next token and going to the corresponding state, or reducing a single rule. In the other cases, i.e., when shifting *and* reducing is possible or when *several* reductions are possible, the lookahead is required to select the action. State 8 is one such state: if the lookahead is ‘\*’ or ‘/’ then the action is shifting, otherwise the action is reducing rule 1. In other words, the first two items, corresponding to rule 1, are not eligible when the lookahead token is ‘\*’, since we specified that ‘\*’ has higher precedence than ‘+’. More generally, some items are eligible only with some set of possible lookahead tokens. When run with --report=lookahead, Bison specifies these lookahead tokens:

State 8

1. exp: exp . ’+’ exp

1 | exp ’+’ exp . [$end, ’+’, ’-’, ’/’]

1. | exp . ’-’ exp
2. | exp . ’\*’ exp
3. | exp . ’/’ exp

’\*’ shift, and go to state 6 ’/’ shift, and go to state 7

’/’ [reduce using rule 1 (exp)]

$default reduce using rule 1 (exp)

Note however that while ‘NUM + NUM / NUM’ is ambiguous (which results in the conflicts on ‘/’), ‘NUM + NUM \* NUM’ is not: the conflict was solved thanks to associativity and precedence directives. If invoked with --report=solved, Bison includes information about the solved conflicts in the report:

Conflict between rule 1 and token ’+’ resolved as reduce (left ’+’). Conflict between rule 1 and token ’-’ resolved as reduce (left ’-’). Conflict between rule 1 and token ’\*’ resolved as shift (’+’ < ’\*’).

The remaining states are similar:

State 9

1. exp: exp . ’+’ exp
2. | exp . ’-’ exp
3. | exp ’-’ exp .
4. | exp . ’\*’ exp
5. | exp . ’/’ exp

’\*’ shift, and go to state 6 ’/’ shift, and go to state 7

’/’ [reduce using rule 2 (exp)]

$default reduce using rule 2 (exp) State 10

1. exp: exp . ’+’ exp
2. | exp . ’-’ exp
3. | exp . ’\*’ exp
4. | exp ’\*’ exp .
5. | exp . ’/’ exp

’/’ shift, and go to state 7

’/’ [reduce using rule 3 (exp)]

$default reduce using rule 3 (exp) State 11

1. exp: exp . ’+’ exp
2. | exp . ’-’ exp
3. | exp . ’\*’ exp
4. | exp . ’/’ exp

4 | exp ’/’ exp .

’+’ shift, and go to state 4 ’-’ shift, and go to state 5 ’\*’ shift, and go to state 6 ’/’ shift, and go to state 7

’+’ [reduce using rule 4 (exp)] ’-’ [reduce using rule 4 (exp)] ’\*’ [reduce using rule 4 (exp)] ’/’ [reduce using rule 4 (exp)]

$default reduce using rule 4 (exp)

Observe that state 11 contains conflicts not only due to the lack of precedence of ‘/’ with respect to ‘+’, ‘-’, and ‘\*’, but also because the associativity of ‘/’ is not specified.

Bison may also produce an HTML version of this output, via an XML file and XSLT processing (see [Section 8.3 [Visualizing your parser in multiple formats], page 142](#_bookmark186)).

## Visualizing Your Parser

As another means to gain better understanding of the shift/reduce automaton corresponding to the Bison parser, a DOT file can be generated. Note that debugging a real grammar with this is tedious at best, and impractical most of the times, because the generated files are huge (the generation of a PDF or PNG file from it will take very long, and more often than not it will fail due to memory exhaustion). This option was rather designed for beginners, to help them understand LR parsers.

This file is generated when the --graph option is specified (see [Chapter 9 [Invoking](#_bookmark194) [Bison], page 149](#_bookmark194)). Its name is made by removing ‘.tab.c’ or ‘.c’ from the parser imple- mentation file name, and adding ‘.dot’ instead. If the grammar file is foo.y, the Graphviz output file is called foo.dot. A DOT file may also be produced via an XML file and XSLT processing (see [Section 8.3 [Visualizing your parser in multiple formats], page 142](#_bookmark186)).

The following grammar file, rr.y, will be used in the sequel:



exp: a ";" | b "."; a: "0";

b: "0";

The graphical output (see [Figure 8.1](#_bookmark184)) is very similar to the textual one, and as such it is easier understood by making direct comparisons between them. See [Chapter 8 [Debugging](#_bookmark177) [Your Parser], page 133](#_bookmark177), for a detailled analysis of the textual report.

"0"

State 1

3 a: "0" . [";"]

4 b: "0" . ["."]

exp

State 0

0 $accept: . exp $end 1 exp: . a ";"

2 | . b "."

3 a: . "0"

4 b: . "0"



a

b

R3

["."]

R4

|  |  |
| --- | --- |
| State 2  0 $accept: exp . $end | |
|  | $end |

|  |  |
| --- | --- |
| State 3  1 exp: a . ";" | |
|  | ";" |

|  |  |
| --- | --- |
| State 4  2 exp: b . "." | |
|  | "." |

Acc

R1

R2

Figure 8.1: A graphical rendering of the parser.

State 7

2 exp: b "." .

State 6

1 exp: a ";" .

State 5

0 $accept: exp $end .

#### Graphical Representation of States

The items (pointed rules) for each state are grouped together in graph nodes. Their num- bering is the same as in the verbose file. See the following points, about transitions, for examples

When invoked with --report=lookaheads, the lookahead tokens, when needed, are shown next to the relevant rule between square brackets as a comma separated list. This is the case in the figure for the representation of reductions, below.

The transitions are represented as directed edges between the current and the target states.

#### Graphical Representation of Shifts

Shifts are shown as solid arrows, labelled with the lookahead token for that shift. The following describes a reduction in the rr.output file:

State 3

1 exp: a . ";"

";" shift, and go to state 6

A Graphviz rendering of this portion of the graph could be:

|  |  |
| --- | --- |
| State 3  1 exp: a . "." | |
|  | "." |

State 6

1 exp: a "." .

#### Graphical Representation of Reductions

Reductions are shown as solid arrows, leading to a diamond-shaped node bearing the number of the reduction rule. The arrow is labelled with the appropriate comma separated lookahead tokens. If the reduction is the default action for the given state, there is no such label.

This is how reductions are represented in the verbose file rr.output: State 1

3 a: "0" . [";"]

4 b: "0" . ["."]

"." reduce using rule 4 (b)

$default reduce using rule 3 (a)

A Graphviz rendering of this portion of the graph could be:



R3

State 1

3 a: "0" . ["."]

4 b: "0" . [";"]

When unresolved conflicts are present, because in deterministic parsing a single de- cision can be made, Bison can arbitrarily choose to disable a reduction, see [Section 5.2](#_bookmark143) [[Shift/Reduce Conflicts], page 108](#_bookmark143). Discarded actions are distinguished by a red filling color on these nodes, just like how they are reported between square brackets in the verbose file.



[";"]

R4

The reduction corresponding to the rule number 0 is the acceptation state. It is shown as a blue diamond, labelled “Acc”.

#### Graphical representation of go tos

The ‘go to’ jump transitions are represented as dotted lines bearing the name of the rule being jumped to.

## Visualizing your parser in multiple formats

Bison supports two major report formats: textual output (see [Section 8.1 [Understanding](#_bookmark178) [Your Parser], page 133](#_bookmark178)) when invoked with option --verbose, and DOT (see [Section 8.2](#_bookmark183) [[Visualizing Your Parser], page 140](#_bookmark183)) when invoked with option --graph. However, another

alternative is to output an XML file that may then be, with xsltproc, rendered as either a raw text format equivalent to the verbose file, or as an HTML version of the same file, with clickable transitions, or even as a DOT. The .output and DOT files obtained via XSLT have no difference whatsoever with those obtained by invoking bison with options

--verbose or --graph.

The XML file is generated when the options -x or --xml[=FILE] are specified, see [Chapter 9 [Invoking Bison], page 149](#_bookmark194). If not specified, its name is made by removing ‘.tab.c’ or ‘.c’ from the parser implementation file name, and adding ‘.xml’ instead. For instance, if the grammar file is foo.y, the default XML output file is foo.xml.

Bison ships with a data/xslt directory, containing XSL Transformation files to apply to the XML file. Their names are non-ambiguous:

xml2dot.xsl

Used to output a copy of the DOT visualization of the automaton.

xml2text.xsl

Used to output a copy of the ‘.output’ file.

xml2xhtml.xsl

Used to output an xhtml enhancement of the ‘.output’ file.

Sample usage (requires xsltproc):

$ bison -x gr.y

$ bison --print-datadir

/usr/local/share/bison

$ xsltproc /usr/local/share/bison/xslt/xml2xhtml.xsl gr.xml >gr.html

## Tracing Your Parser

When a Bison grammar compiles properly but parses “incorrectly”, the yydebug parser- trace feature helps figuring out why.

#### Enabling Traces

There are several means to enable compilation of trace facilities: the macro YYDEBUG

Define the macro YYDEBUG to a nonzero value when you compile the parser. This is compliant with POSIX Yacc. You could use ‘-DYYDEBUG=1’ as a compiler option or you could put ‘#define YYDEBUG 1’ in the prologue of the grammar file (see [Section 3.1.1 [The Prologue], page 51](#_bookmark46)).

If the define variable api.prefix is used (see [Section 3.8 [Multiple Parsers](#_bookmark118) [in the Same Program], page 94](#_bookmark118)), for instance ‘ define api.prefix x’, then if CDEBUG is defined, its value controls the tracing feature (enabled if and only if nonzero); otherwise tracing is enabled if and only if YYDEBUG is nonzero.

the option -t (POSIX Yacc compliant) the option --debug (Bison extension)

Use the ‘-t’ option when you run Bison (see [Chapter 9 [Invoking Bison],](#_bookmark194) [page 149](#_bookmark194)). With ‘define api.prefix {c}’, it defines CDEBUG to 1, otherwise it defines YYDEBUG to 1.

the directive ‘debug’

Add the debug directive (see [Section 3.7.12 [Bison Declaration Summary],](#_bookmark105) [page 83](#_bookmark105)). This Bison extension is maintained for backward compatibility with previous versions of Bison.

the variable ‘parse.trace’

Add the ‘define parse.trace’ directive (see [Section 3.7.13 [parse.trace],](#_bookmark109) [page 86](#_bookmark109)), or pass the -Dparse.trace option (see [Section 9.1 [Bison Options],](#_bookmark195) [page 149](#_bookmark195)). This is a Bison extension, which is especially useful for languages that don’t use a preprocessor. Unless POSIX and Yacc portability matter to you, this is the preferred solution.

We suggest that you always enable the trace option so that debugging is always possible. The trace facility outputs messages with macro calls of the form YYFPRINTF (stderr,

*format*, *args*) where *format* and *args* are the usual printf format and variadic argu-

ments. If you define YYDEBUG to a nonzero value but do not define YYFPRINTF, <stdio.h>

is automatically included and YYFPRINTF is defined to fprintf.

Once you have compiled the program with trace facilities, the way to request a trace is to store a nonzero value in the variable yydebug. You can do this by making the C code do it (in main, perhaps), or you can alter the value with a C debugger.

Each step taken by the parser when yydebug is nonzero produces a line or two of trace information, written on stderr. The trace messages tell you these things:

* + - * Each time the parser calls yylex, what kind of token was read.

Each time a token is shifted, the depth and complete contents of the state stack (see [Section 5.5 [Parser States], page 113](#_bookmark151)).

*•*

Each time a rule is reduced, which rule it is, and the complete contents of the state stack afterward.

*•*

To make sense of this information, it helps to refer to the automaton description file (see [Section 8.1 [Understanding Your Parser], page 133](#_bookmark178)). This file shows the meaning of each state in terms of positions in various rules, and also what each state will do with each possible input token. As you read the successive trace messages, you can see that the parser is functioning according to its specification in the listing file. Eventually you will arrive at the place where something undesirable happens, and you will see which parts of the grammar are to blame.

The parser implementation file is a C/C++/Java program and you can use debuggers on it, but it’s not easy to interpret what it is doing. The parser function is a finite-state machine interpreter, and aside from the actions it executes the same code over and over. Only the values of variables show where in the grammar it is working.

#### Enabling Debug Traces for mfcalc

The debugging information normally gives the token type of each token read, but not its semantic value. The printer directive allows specify how semantic values are reported, see [Section 3.7.7 [Printing Semantic Values], page 79](#_bookmark98). For backward compatibility, Yacc like C parsers may also use the YYPRINT (see [Section 8.4.3 [The YYPRINT Macro], page 147](#_bookmark193)), but its use is discouraged.

As a demonstration of printer, consider the multi-function calculator, mfcalc (see [Section 2.5 [Multi-function Calc], page 42](#_bookmark37)). To enable run-time traces, and semantic value reports, insert the following directives in its prologue:

/\* Generate the parser description file. \*/ verbose

/\* Enable run-time traces (yydebug). \*/ define parse.trace

/\* Formatting semantic values. \*/

printer { fprintf (yyoutput, "s", $$->name); } VAR; printer { fprintf (yyoutput, "s()", $$->name); } FNCT; printer { fprintf (yyoutput, "g", $$); } <double>;

The define directive instructs Bison to generate run-time trace support. Then, acti- vation of these traces is controlled at run-time by the yydebug variable, which is disabled by default. Because these traces will refer to the “states” of the parser, it is helpful to ask for the creation of a description of that parser; this is the purpose of (admittedly ill-named) verbose directive.

The set of printer directives demonstrates how to format the semantic value in the traces. Note that the specification can be done either on the symbol type (e.g., VAR or FNCT), or on the type tag: since <double> is the type for both NUM and exp, this printer will be used for them.

Here is a sample of the information provided by run-time traces. The traces are sent onto standard error.

$ *echo ’sin(1-1)’* | *./mfcalc -p*

Starting parse Entering state 0

Reducing stack by rule 1 (line 34):

-> $$ = nterm input () Stack now 0

Entering state 1

This first batch shows a specific feature of this grammar: the first rule (which is in line 34 of mfcalc.y can be reduced without even having to look for the first token. The resulting left-hand symbol ($$) is a valueless (‘()’) input non terminal (nterm).

Then the parser calls the scanner.

Reading a token: Next token is token FNCT (sin()) Shifting token FNCT (sin())

Entering state 6

That token (token) is a function (FNCT) whose value is ‘sin’ as formatted per our printer specification: ‘sin()’. The parser stores (Shifting) that token, and others, until it can do something about it.

Reading a token: Next token is token ’(’ () Shifting token ’(’ ()

Entering state 14

Reading a token: Next token is token NUM (1.000000) Shifting token NUM (1.000000)

Entering state 4

Reducing stack by rule 6 (line 44):

$1 = token NUM (1.000000)

-> $$ = nterm exp (1.000000) Stack now 0 1 6 14

Entering state 24

The previous reduction demonstrates the printer directive for <double>: both the token

NUM and the resulting nonterminal exp have ‘1’ as value.

Reading a token: Next token is token ’-’ () Shifting token ’-’ ()

Entering state 17

Reading a token: Next token is token NUM (1.000000) Shifting token NUM (1.000000)

Entering state 4

Reducing stack by rule 6 (line 44):

$1 = token NUM (1.000000)

-> $$ = nterm exp (1.000000) Stack now 0 1 6 14 24 17

Entering state 26

Reading a token: Next token is token ’)’ () Reducing stack by rule 11 (line 49):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| $1 | = | nterm | exp | (1.000000) |
| $2 | = | token | ’-’ | () |
| $3 | = | nterm | exp | (1.000000) |
| -> $$ | = | nterm | exp | (0.000000) |

Stack now 0 1 6 14

Entering state 24

The rule for the subtraction was just reduced. The parser is about to discover the end of the call to sin.

Next token is token ’)’ () Shifting token ’)’ () Entering state 31

Reducing stack by rule 9 (line 47):

$1 = token FNCT (sin())

$2 = token ’(’ ()

$3 = nterm exp (0.000000)

$4 = token ’)’ ()

-> $$ = nterm exp (0.000000) Stack now 0 1

Entering state 11

Finally, the end-of-line allow the parser to complete the computation, and display its result.

Reading a token: Next token is token ’\n’ () Shifting token ’\n’ ()

Entering state 22

Reducing stack by rule 4 (line 40):

|  |  |  |  |
| --- | --- | --- | --- |
| $1 | = | nterm | exp (0.000000) |
| $2 | = | token | ’\n’ () |

*⇒* 0

-> $$ = nterm line ()

Stack now 0 1

Entering state 10

Reducing stack by rule 2 (line 35):

$1 = nterm input ()

$2 = nterm line ()

-> $$ = nterm input () Stack now 0

Entering state 1

The parser has returned into state 1, in which it is waiting for the next expression to evaluate, or for the end-of-file token, which causes the completion of the parsing.

Reading a token: Now at end of input. Shifting token $end ()

Entering state 2

Stack now 0 1 2

Cleanup: popping token $end () Cleanup: popping nterm input ()

* + 1. **The** YYPRINT **Macro**

Before printer support, semantic values could be displayed using the YYPRINT macro, which works only for terminal symbols and only with the yacc.c skeleton.

YYPRINT (*stream, token, value*)*;* [Macro]

If you define YYPRINT, it should take three arguments. The parser will pass a standard I/O stream, the numeric code for the token type, and the token value (from yylval).

For yacc.c only. Obsoleted by printer.

Here is an example of YYPRINT suitable for the multi-function calculator (see [Section 2.5.1](#_bookmark39) [[Declarations for mfcalc], page 43](#_bookmark39)):

{

static void print\_token\_value (FILE \*, int, YYSTYPE); #define YYPRINT(File, Type, Value) \

print\_token\_value (File, Type, Value)

}

... ... ...



static void

print\_token\_value (FILE \*file, int type, YYSTYPE value)

{

if (type == VAR)

fprintf (file, "s", value.tptr->name); else if (type == NUM)

fprintf (file, "d", value.val);

}

# Invoking Bison

The usual way to invoke Bison is as follows:

bison *infile*

Here *infile* is the grammar file name, which usually ends in ‘.y’. The parser implemen- tation file’s name is made by replacing the ‘.y’ with ‘.tab.c’ and removing any leading directory. Thus, the ‘bison foo.y’ file name yields foo.tab.c, and the ‘bison hack/foo.y’ file name yields foo.tab.c. It’s also possible, in case you are writing C++ code instead of C in your grammar file, to name it foo.ypp or foo.y++. Then, the output files will take an extension like the given one as input (respectively foo.tab.cpp and foo.tab.c++). This feature takes effect with all options that manipulate file names like ‘-o’ or ‘-d’.

For example :

bison -d *infile.yxx*

will produce infile.tab.cxx and infile.tab.hxx, and

bison -d -o *output.c*++ *infile.y*

will produce output.c++ and outfile.h++.

For compatibility with POSIX, the standard Bison distribution also contains a shell script called yacc that invokes Bison with the -y option.

## Bison Options

Bison supports both traditional single-letter options and mnemonic long option names. Long option names are indicated with ‘--’ instead of ‘-’. Abbreviations for option names are allowed as long as they are unique. When a long option takes an argument, like ‘--file-prefix’, connect the option name and the argument with ‘=’.

Here is a list of options that can be used with Bison, alphabetized by short option. It is followed by a cross key alphabetized by long option.

Operations modes:

-h

--help Print a summary of the command-line options to Bison and exit.

-V

--version

Print the version number of Bison and exit.

--print-localedir

Print the name of the directory containing locale-dependent data.

--print-datadir

Print the name of the directory containing skeletons and XSLT.

-y

--yacc Act more like the traditional Yacc command. This can cause different diag- nostics to be generated, and may change behavior in other minor ways. Most importantly, imitate Yacc’s output file name conventions, so that the parser im- plementation file is called y.tab.c, and the other outputs are called y.output and y.tab.h. Also, if generating a deterministic parser in C, generate #define

statements in addition to an enum to associate token numbers with token names. Thus, the following shell script can substitute for Yacc, and the Bison distribu- tion contains such a script for compatibility with POSIX:

#! /bin/sh bison -y "$@"

The -y/--yacc option is intended for use with traditional Yacc grammars. If your grammar uses a Bison extension like ‘ glr-parser’, Bison might not be Yacc-compatible even if this option is specified.

-W [*category*]

--warnings[=*category*]

Output warnings falling in *category*. *category* can be one of:

midrule-values

Warn about mid-rule values that are set but not used within any of the actions of the parent rule. For example, warn about unused

$2 in:

exp: ’1’ { $$ = 1; } ’+’ exp { $$ = $1 + $4; };

Also warn about mid-rule values that are used but not set. For example, warn about unset $$ in the mid-rule action in:

exp: ’1’ { $1 = 1; } ’+’ exp { $$ = $2 + $4; };

These warnings are not enabled by default since they sometimes prove to be false alarms in existing grammars employing the Yacc constructs $0 or $-*n* (where *n* is some positive integer).

yacc Incompatibilities with POSIX Yacc.

conflicts-sr conflicts-rr

S/R and R/R conflicts. These warnings are enabled by default. However, if the expect or expect-rr directive is specified, an unexpected number of conflicts is an error, and an expected number of conflicts is not reported, so -W and --warning then have no effect on the conflict report.

deprecated

empty-rule

precedence

Deprecated constructs whose support will be removed in future versions of Bison.

Empty rules without empty. See [Section 3.3.2 [Empty Rules],](#_bookmark57) [page 60](#_bookmark57). Disabled by default, but enabled by uses of empty, unless

-Wno-empty-rule was specified.

Useless precedence and associativity directives. Disabled by de- fault.

Consider for instance the following grammar:

nonassoc "=" left "+" left "\*" precedence "("



stmt:

exp

| "var" "=" exp

;

exp:

exp "+" exp

| exp "\*" "num"

| "(" exp ")"

| "num"

;

Bison reports:

warning: useless precedence and associativity for "=" nonassoc "="

^^^

warning: useless associativity for "\*", use precedence left "\*"

^^^

warning: useless precedence for "(" precedence "("

^^^

One would get the exact same parser with the following directives instead:

left "+" precedence "\*"

other All warnings not categorized above. These warnings are enabled by default.

This category is provided merely for the sake of completeness. Fu- ture releases of Bison may move warnings from this category to new, more specific categories.

all All the warnings except yacc. none Turn off all the warnings. error See -Werror, below.

A category can be turned off by prefixing its name with ‘no-’. For instance,

-Wno-yacc will hide the warnings about POSIX Yacc incompatibilities.

-Werror Turn enabled warnings for every *category* into errors, unless they are explicitly disabled by -Wno-error=*category*.

-Werror=*category*

Enable warnings falling in *category*, and treat them as errors.

*category* is the same as for --warnings, with the exception that it may not be prefixed with ‘no-’ (see above).

Note that the precedence of the ‘=’ and ‘,’ operators is such that the following commands are *not* equivalent, as the first will not treat S/R conflicts as errors.

$ bison -Werror=yacc,conflicts-sr input.y

$ bison -Werror=yacc,error=conflicts-sr input.y

-Wno-error

Do not turn enabled warnings for every *category* into errors, unless they are explicitly enabled by -Werror=*category*.

-Wno-error=*category*

Deactivate the error treatment for this *category*. However, the warning itself won’t be disabled, or enabled, by this option.

-f [*feature*]

--feature[=*feature*]

Activate miscellaneous *feature*. *feature* can be one of:

caret

diagnostics-show-caret

Show caret errors, in a manner similar to GCC’s -fdiagnostics- show-caret, or Clang’s -fcaret-diagnotics. The location pro- vided with the message is used to quote the corresponding line of the source file, underlining the important part of it with carets (‘^’). Here is an example, using the following file in.y:

type <ival> exp



exp: exp ’+’ exp { $exp = $1 + $2; };

When invoked with -fcaret (or nothing), Bison will report: in.y:3.20-23: error: ambiguous reference: ’$exp’ exp: exp ’+’ exp { $exp = $1 + $2; };

^^^^

in.y:3.1-3: refers to: $exp at $$ exp: exp ’+’ exp { $exp = $1 + $2; };

^^^

in.y:3.6-8: refers to: $exp at $1 exp: exp ’+’ exp { $exp = $1 + $2; };

^^^

in.y:3.14-16: refers to: $exp at $3 exp: exp ’+’ exp { $exp = $1 + $2; };

^^^

in.y:3.32-33: error: $2 of ’exp’ has no declared type exp: exp ’+’ exp { $exp = $1 + $2; };

^^

Whereas, when invoked with -fno-caret, Bison will only report:

in.y:3.20-23: error: ambiguous reference: ‘$exp’ in.y:3.1-3: refers to: $exp at $$ in.y:3.6-8: refers to: $exp at $1 in.y:3.14-16: refers to: $exp at $3

in.y:3.32-33: error: $2 of ‘exp’ has no declared type

This option is activated by default.

Tuning the parser:

-t

--debug In the parser implementation file, define the macro YYDEBUG to 1 if it is not already defined, so that the debugging facilities are compiled. See [Section 8.4](#_bookmark188) [[Tracing Your Parser], page 143](#_bookmark188).

-D *name*[=*value*]

--define=*name*[=*value*]

-F *name*[=*value*]

--force-define=*name*[=*value*]

Each of these is equivalent to ‘define *name* "*value*"’ (see [Section 3.7.13 [%de-](#_bookmark109) [fine Summary], page 86](#_bookmark109)) except that Bison processes multiple definitions for the same *name* as follows:

* Bison quietly ignores all command-line definitions for *name* except the last. If that command-line definition is specified by a -D or --define, Bison reports an error for any define definition for *name*.

*•*

If that command-line definition is specified by a -F or --force-define

*•*

instead, Bison quietly ignores all define definitions for *name*.

Otherwise, Bison reports an error if there are multiple define definitions for *name*.

*•*

You should avoid using -F and --force-define in your make files unless you are confident that it is safe to quietly ignore any conflicting define that may be added to the grammar file.

-L *language*

--language=*language*

Specify the programming language for the generated parser, as if language was specified (see [Section 3.7.12 [Bison Declaration Summary], page 83](#_bookmark105)). Currently supported languages include C, C++, and Java. *language* is case-insensitive.

--locations

Pretend that locations was specified. See [Section 3.7.12 [Decl Summary],](#_bookmark105) [page 83](#_bookmark105).

-p *prefix*

--name-prefix=*prefix*

Pretend that name-prefix "*prefix*" was specified (see [Section 3.7.12 [Decl](#_bookmark105) [Summary], page 83](#_bookmark105)). Obsoleted by -Dapi.prefix=*prefix*. See [Section 3.8](#_bookmark118) [[Multiple Parsers in the Same Program], page 94](#_bookmark118).

-l

--no-lines

-S *file*

Don’t put any #line preprocessor commands in the parser implementation file. Ordinarily Bison puts them in the parser implementation file so that the C compiler and debuggers will associate errors with your source file, the grammar file. This option causes them to associate errors with the parser implementation file, treating it as an independent source file in its own right.

--skeleton=*file*

Specify the skeleton to use, similar to skeleton (see [Section 3.7.12 [Bison](#_bookmark105) [Declaration Summary], page 83](#_bookmark105)).

If *file* does not contain a /, *file* is the name of a skeleton file in the Bison installation directory. If it does, *file* is an absolute file name or a file name relative to the current working directory. This is similar to how most shells resolve commands.

-k

--token-table

Pretend that token-table was specified. See [Section 3.7.12 [Decl Summary],](#_bookmark105) [page 83](#_bookmark105).

Adjust the output:

--defines[=*file*]

Pretend that defines was specified, i.e., write an extra output file containing macro definitions for the token type names defined in the grammar, as well as a few other declarations. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

-d This is the same as --defines except -d does not accept a *file* argument since POSIX Yacc requires that -d can be bundled with other short options.

-b *file-prefix*

--file-prefix=*prefix*

Pretend that file-prefix was specified, i.e., specify prefix to use for all Bison output file names. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

-r *things*

--report=*things*

Write an extra output file containing verbose description of the comma sepa- rated list of *things* among:

state Description of the grammar, conflicts (resolved and unresolved), and parser’s automaton.

itemset Implies state and augments the description of the automaton with the full set of items for each state, instead of its core only.

lookahead

Implies state and augments the description of the automaton with each rule’s lookahead set.

solved Implies state. Explain how conflicts were solved thanks to prece- dence and associativity directives.

all Enable all the items.

none Do not generate the report.

--report-file=*file*

Specify the *file* for the verbose description.

-v

--verbose

-o *file*

Pretend that verbose was specified, i.e., write an extra output file contain- ing verbose descriptions of the grammar and parser. See [Section 3.7.12 [Decl](#_bookmark105) [Summary], page 83](#_bookmark105).

--output=*file*

Specify the *file* for the parser implementation file.

The other output files’ names are constructed from *file* as described under the ‘-v’ and ‘-d’ options.

-g [*file*]

--graph[=*file*]

Output a graphical representation of the parser’s automaton computed by Bi- son, in [Graphviz (http://www.graphviz.org/)](http://www.graphviz.org/) [DOT (http://www.graphviz.](http://www.graphviz.org/doc/info/lang.html) [org/doc/info/lang.html)](http://www.graphviz.org/doc/info/lang.html) format. *file* is optional. If omitted and the gram- mar file is foo.y, the output file will be foo.dot.

-x [*file*]

--xml[=*file*]

Output an XML report of the parser’s automaton computed by Bison. *file* is optional. If omitted and the grammar file is foo.y, the output file will be foo.xml.

## Option Cross Key

Here is a list of options, alphabetized by long option, to help you find the corresponding short option and directive.

|  |  |  |
| --- | --- | --- |
| **Long Option** | **Short Option** | **Bison Directive** |
| --debug | -t | debug |
| --define=*name*[=*value*] | -D *name*[=*value*] | define *name* ["*value*"] |
| --defines[=*file*] | -d | defines ["*file*"] |
| --feature[=*feature*]  --file-prefix=*prefix* | -f [*feature*]  -b *prefix* | file-prefix "*prefix*" |
| --force-define=*name*[=*value*] | -F *name*[=*value*] | define *name* ["*value*"] |
| --graph[=*file*] | -g [*file*] |  |

--help -h

--language=*language* -L *language *language "*language*"

--locations locations

--name-prefix=*prefix* -p *prefix *name-prefix "*prefix*"

--no-lines -l no-lines

--output=*file* -o *file *output "*file*"

--print-datadir

--print-localedir

--report-file=*file*

--report=*things* -r *things*

--skeleton=*file* -S *file *skeleton "*file*"

--token-table -k token-table

--verbose -v verbose

--version -V

--warnings[=*category*] -W [*category*]

--xml[=*file*] -x [*file*]

--yacc -y yacc

## Yacc Library

The Yacc library contains default implementations of the yyerror and main functions. These default implementations are normally not useful, but POSIX requires them. To use the Yacc library, link your program with the -ly option. Note that Bison’s implementation of the Yacc library is distributed under the terms of the GNU General Public License (see [[Copying], page 5](#_bookmark2)).

If you use the Yacc library’s yyerror function, you should declare yyerror as follows:

int yyerror (char const \*);

The int value returned by this yyerror is ignored.

The implementation of Yacc library’s main function is:

int main (void)

{

setlocale (LC\_ALL, ""); return yyparse ();

}

so if you use it, the internationalization support is enabled (e.g., error messages are trans- lated), and your yyparse function should have the following type signature:

int yyparse (void);

# Parsers Written In Other Languages

* 1. **C**++ **Parsers**

#### C++ Bison Interface

The C++ deterministic parser is selected using the skeleton directive, ‘ skeleton "lalr1.cc"’, or the synonymous command-line option --skeleton=lalr1.cc. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

When run, bison will create several entities in the ‘yy’ namespace. Use the ‘define api.namespace’ directive to change the namespace name, see [Section 3.7.13](#_bookmark109) [[api.namespace], page 86](#_bookmark109). The various classes are generated in the following files:

position.hh location.hh

The definition of the classes position and location, used for location tracking when enabled. These files are not generated if the define variable api.location.type is defined. See [Section 10.1.3 [C++ Location Values],](#_bookmark204) [page 159](#_bookmark204).

stack.hh An auxiliary class stack used by the parser.

*file*.hh

*file*.cc (Assuming the extension of the grammar file was ‘.yy’.) The declaration and implementation of the C++ parser class. The basename and extension of these two files follow the same rules as with regular C parsers (see [Chapter 9 [Invo-](#_bookmark194) [cation], page 149](#_bookmark194)).

The header is *mandatory*; you must either pass -d/--defines to bison, or use the ‘defines’ directive.

All these files are documented using Doxygen; run doxygen for a complete and accurate documentation.

#### C++ Semantic Values

Bison supports two different means to handle semantic values in C++. One is alike the C interface, and relies on unions (see [Section 10.1.2.1 [C++ Unions], page 157](#_bookmark200)). As C++ practitioners know, unions are inconvenient in C++, therefore another approach is provided, based on variants (see [Section 10.1.2.2 [C++ Variants], page 158](#_bookmark202)).

* + - 1. **C**++ **Unions**

The union directive works as for C, see [Section 3.4.4 [The Union Declaration], page 63](#_bookmark66). In particular it produces a genuine union, which have a few specific features in C++.

The type YYSTYPE is defined but its use is discouraged: rather you should refer to the parser’s encapsulated type yy::parser::semantic\_type.

*−*

Non POD (Plain Old Data) types cannot be used. C++ forbids any instance of classes with constructors in unions: only *pointers* to such objects are allowed.

*−*

Because objects have to be stored via pointers, memory is not reclaimed automatically: using the destructor directive is the only means to avoid leaks. See [Section 3.7.6 [Freeing](#_bookmark95) [Discarded Symbols], page 77](#_bookmark95).

* + - 1. **C**++ **Variants**

Bison provides a *variant* based implementation of semantic values for C++. This alleviates all the limitations reported in the previous section, and in particular, object types can be used without pointers.

To enable variant-based semantic values, set define variable variant (see [Section 3.7.13 [variant], page 86](#_bookmark109)). Once this defined, union is ignored, and instead of using the name of the fields of the union to “type” the symbols, use genuine types.

For instance, instead of:

union

{

int ival; std::string\* sval;

}

write:

token <ival> NUMBER; token <sval> STRING;

token <int> NUMBER;

token <std::string> STRING;

STRING is no longer a pointer, which should fairly simplify the user actions in the gram- mar and in the scanner (in particular the memory management).

Since C++ features destructors, and since it is customary to specialize operator<< to support uniform printing of values, variants also typically simplify Bison printers and de- structors.

Variants are stricter than unions. When based on unions, you may play any dirty game with yylval, say storing an int, reading a char\*, and then storing a double in it. This is no longer possible with variants: they must be initialized, then assigned to, and eventually, destroyed. As a matter of fact, Bison variants forbid the use of alternative types such as ‘$<int>2’ or ‘$<std::string>$’, even in mid-rule actions. It is mandatory to use typed mid-rule actions (see [Section 3.4.8.2 [Typed Mid-Rule Actions], page 67](#_bookmark74)).

T& build<T> () [Method on semantic\_type]

Initialize, but leave empty. Returns the address where the actual value may be stored. Requires that the variant was not initialized yet.

T& build<T> (*const T& t*)

Initialize, and copy-construct from *t*.

[Method on semantic\_type]

**Warning**: We do not use Boost.Variant, for two reasons. First, it appeared unacceptable to require Boost on the user’s machine (i.e., the machine on which the generated parser will be compiled, not the machine on which bison was run). Second, for each possible semantic value, Boost.Variant not only stores the value, but also a tag specifying its type. But the

parser already “knows” the type of the semantic value, so that would be duplicating the information.

We do not use C++17’s std::variant either: we want to support all the C++ standards, and of course std::variant also stores a tag to record the current type.

Therefore we developed light-weight variants whose type tag is external (so they are really like unions for C++ actually). There is a number of limitations in (the current implementation of) variants:

Alignment must be enforced: values should be aligned in memory according to the most demanding type. Computing the smallest alignment possible requires meta- programming techniques that are not currently implemented in Bison, and therefore, since, as far as we know, double is the most demanding type on all platforms, align- ments are enforced for double whatever types are actually used. This may waste space in some cases.

*•*

* + - * + Move semantics is not yet supported, but will soon be added.
        + There might be portability issues we are not aware of.

As far as we know, these limitations *can* be alleviated. All it takes is some time and/or some talented C++ hacker willing to contribute to Bison.

#### C++ Location Values

When the directive locations is used, the C++ parser supports location tracking, see [Section 3.5 [Tracking Locations], page 71](#_bookmark79).

By default, two auxiliary classes define a position, a single point in a file, and a location, a range composed of a pair of positions (possibly spanning several files). But if the define variable api.location.type is defined, then these classes will not be gen- erated, and the user defined type will be used.

##### **C**++ position

position (*std::string\* file = 0, unsigned line = 1,* unsigned *col = 1*)

[Constructor on position]

Create a position denoting a given point. Note that file is not reclaimed when the

position is destroyed: memory managed must be handled elsewhere.

void initialize (*std::string\* file = 0, unsigned line*

*= 1, unsigned col = 1*)

Reset the position to the given values.

[Method on position]

std::string\* file [Instance Variable of position]

The name of the file. It will always be handled as a pointer, the parser will never duplicate nor deallocate it. As an experimental feature you may change it to ‘*type*\*’ using ‘define filename\_type "*type*"’.

unsigned line

The line, starting at 1.

void lines (*int height = 1*)

[Instance Variable of position]

[Method on position]

If *height* is not null, advance by *height* lines, resetting the column number. The resulting line number cannot be less than 1.

###### unsigned column

The column, starting at 1.

[Instance Variable of position]

void columns (*int width = 1*) [Method on position]

Advance by *width* columns, without changing the line number. The resulting column number cannot be less than 1.

position& operator+= (*int width*) position operator+ (*int width*) position& operator-= (*int width*) position operator- (*int width*)

Various forms of syntactic sugar for columns.

[Method on position] [Method on position] [Method on position] [Method on position]

bool operator== (*const position& that*)

bool operator!= (*const position& that*)

Whether \*this and that denote equal/different positions.

[Method on position] [Method on position]

std::ostream& operator<< (*std::ostream& o, const position& p*) [Function]

Report *p* on *o* like this: ‘*file*:*line*.*column*’, or ‘*line*.*column*’ if *file* is null.

##### **C**++ location

location (*const position& begin, const position&*

*end*)

Create a Location from the endpoints of the range.

[Constructor on location]

location (*const position& pos = position*())

location (*std::string\* file, unsigned line, unsigned*

*col*)

[Constructor on location] [Constructor on location]

Create a Location denoting an empty range located at a given point.

void initialize (*std::string\* file = 0, unsigned line*

*= 1, unsigned col = 1*)

Reset the location to an empty range at the given values.

[Method on location]

position begin position end

[Instance Variable of location] [Instance Variable of location]

The first, inclusive, position of the range, and the first beyond.

void columns (*int width = 1*)

void lines (*int height = 1*)

Forwarded to the end position.

[Method on location] [Method on location]

location operator+ (*int width*) location operator+= (*int width*) location operator- (*int width*) location operator-= (*int width*)

Various forms of syntactic sugar for columns.

[Method on location] [Method on location] [Method on location] [Method on location]

location operator+ (*const location& end*)

location operator+= (*const location& end*)

[Method on location] [Method on location]

Join two locations: starts at the position of the first one, and ends at the position of the second.

###### void step ()

Move begin onto end.

[Method on location]

bool operator== (*const location& that*)

bool operator!= (*const location& that*)

[Method on location] [Method on location]

Whether \*this and that denote equal/different ranges of positions.

std::ostream& operator<< (*std::ostream& o, const location& p*) [Function]

Report *p* on *o*, taking care of special cases such as: no filename defined, or equal filename/line or column.

#### User Defined Location Type

Instead of using the built-in types you may use the define variable api.location.type

to specify your own type:

define api.location.type {*LocationType*}

The requirements over your *LocationType* are:

* + - * + it must be copyable;
        + in order to compute the (default) value of @$ in a reduction, the parser basically runs

@$.begin = @1.begin;

@$.end = @*N*.end; // The location of last right-hand side symbol.

so there must be copyable begin and end members;

alternatively you may redefine the computation of the default location, in which case these members are not required (see [Section 3.5.3 [Location Default Action], page 73](#_bookmark83));

*•*

if traces are enabled, then there must exist an ‘std::ostream& operator<< (std::ostream& o, const *LocationType*& s)’ function.

*•*

In programs with several C++ parsers, you may also use the define variable api.location.type to share a common set of built-in definitions for position and location. For instance, one parser master/parser.yy might use:

defines locations

define api.namespace {master::}

to generate the master/position.hh and master/location.hh files, reused by other parsers as follows:

define api.location.type {master::location} code requires { #include <master/location.hh> }

#### C++ Parser Interface

The output files *output*.hh and *output*.cc declare and define the parser class in the namespace yy. The class name defaults to parser, but may be changed using ‘ define parser\_class\_name {*name*}’. The interface of this class is detailed below. It can be ex- tended using the parse-param feature: its semantics is slightly changed since it describes an additional member of the parser class, and an additional argument for its constructor.

###### semantic\_type location\_type

The types for semantic values and locations (if enabled).

[Type of parser] [Type of parser]

token [Type of parser]

A structure that contains (only) the yytokentype enumeration, which defines the tokens. To refer to the token FOO, use yy::parser::token::FOO. The scanner can use ‘typedef yy::parser::token token;’ to “import” the token enumeration (see [Section 10.1.6.4 [Calc++ Scanner], page 169](#_bookmark217)).

syntax\_error [Type of parser]

This class derives from std::runtime\_error. Throw instances of it from the scanner or from the actions to raise parse errors. This is equivalent with first invoking error to report the location and message of the syntax error, and then to invoke YYERROR to enter the error-recovery mode. But contrary to YYERROR which can only be invoked from user actions (i.e., written in the action itself), the exception can be thrown from function invoked from the user action.

parser (*type1 arg1, ...*) [Method on parser]

Build a new parser object. There are no arguments by default, unless ‘ parse-param

{*type1 arg1*}’ was used.

syntax\_error (*const location type& l, const std::string& m*)

syntax\_error (*const std::string& m*)

Instantiate a syntax-error exception.

[Method on syntax\_error] [Method on syntax\_error]

int parse () [Method on parser]

Run the syntactic analysis, and return 0 on success, 1 otherwise.

The whole function is wrapped in a try/catch block, so that when an exception is thrown, the destructors are called to release the lookahead symbol, and the symbols pushed on the stack.

Exception related code in the generated parser is protected by CPP guards (#if) and disabled when exceptions are not supported (i.e., passing -fno-exceptions to the C++ compiler).

###### std::ostream& debug\_stream ()

void set\_debug\_stream (*std::ostream& o*)

[Method on parser] [Method on parser]

Get or set the stream used for tracing the parsing. It defaults to std::cerr.

###### debug\_level\_type debug\_level ()

void set\_debug\_level (*debug level l*)

[Method on parser] [Method on parser]

Get or set the tracing level. Currently its value is either 0, no trace, or nonzero, full tracing.

void error (*const location type& l, const std::string& m*)

void error (*const std::string& m*)

[Method on parser] [Method on parser]

The definition for this member function must be supplied by the user: the parser uses it to report a parser error occurring at *l*, described by *m*. If location tracking is not enabled, the second signature is used.

#### C++ Scanner Interface

The parser invokes the scanner by calling yylex. Contrary to C parsers, C++ parsers are always pure: there is no point in using the ‘define api.pure’ directive. The actual interface with yylex depends whether you use unions, or variants.

#### Split Symbols

The interface is as follows.

int yylex (*semantic type\* yylval, location type\* yylloc, type1 arg1, ...*)

int yylex (*semantic type\* yylval, type1 arg1, ...*)

[Method on parser]

[Method on parser]

Return the next token. Its type is the return value, its semantic value and location (if enabled) being *yylval* and *yylloc*. Invocations of ‘lex-param {*type1 arg1*}’ yield additional arguments.

Note that when using variants, the interface for yylex is the same, but yylval is handled differently.

Regular union-based code in Lex scanner typically look like:

[0-9]+ {

}

[a-z]+ {

}

yylval->ival = text\_to\_int (yytext); return yy::parser::token::INTEGER;

yylval->sval = new std::string (yytext); return yy::parser::token::IDENTIFIER;

Using variants, yylval is already constructed, but it is not initialized. So the code would look like:

[0-9]+ {

}

[a-z]+ {

}

yylval->build<int> () = text\_to\_int (yytext); return yy::parser::token::INTEGER;

yylval->build<std::string> () = yytext; return yy::parser::token::IDENTIFIER;

or

[0-9]+ {

}

[a-z]+ {

}

yylval->build (text\_to\_int (yytext)); return yy::parser::token::INTEGER;

yylval->build (yytext);

return yy::parser::token::IDENTIFIER;

#### Complete Symbols

If you specified both define api.value.type variant and define api.token.constructor, the parser class also defines the class parser::symbol\_type which defines a *complete* symbol, aggregating its type (i.e., the traditional value returned by yylex), its semantic value (i.e., the value passed in yylval, and possibly its location (yylloc).

symbol\_type (*token type type, const semantic type&*

*value, const location type& location*)

[Method on symbol\_type]

Build a complete terminal symbol which token type is *type*, and which semantic value is *value*. If location tracking is enabled, also pass the *location*.

This interface is low-level and should not be used for two reasons. First, it is inconvenient, as you still have to build the semantic value, which is a variant, and second, because consistency is not enforced: as with unions, it is still possible to give an integer as semantic value for a string.

So for each token type, Bison generates named constructors as follows.

make\_*token* (*const value\_type& value, const* location type& *location*)

make\_*token* (*const location type& location*)

[Method on symbol\_type]

[Method on symbol\_type]

Build a complete terminal symbol for the token type *token* (not including the api.token.prefix) whose possible semantic value is *value* of adequate *value type*. If location tracking is enabled, also pass the *location*.

For instance, given the following declarations: define api.token.prefix {TOK\_} token <std::string> IDENTIFIER; token <int> INTEGER;

token COLON;

Bison generates the following functions:

symbol\_type make\_IDENTIFIER (const std::string&, const location\_type&); symbol\_type make\_INTEGER (const int&, const location\_type&); symbol\_type make\_COLON (const location\_type&);

which should be used in a Lex-scanner as follows.

[0-9]+ return yy::parser::make\_INTEGER (text\_to\_int (yytext), loc); [a-z]+ return yy::parser::make\_IDENTIFIER (yytext, loc);

":" return yy::parser::make\_COLON (loc);

Tokens that do not have an identifier are not accessible: you cannot simply use characters such as ’:’, they must be declared with token.

#### A Complete C++ Example

This section demonstrates the use of a C++ parser with a simple but complete exam- ple. This example should be available on your system, ready to compile, in the directory

*.../share/doc/bison/examples/calc*++. It focuses on the use of Bison, therefore the design of the various C++ classes is very naive: no accessors, no encapsulation of members etc. We will use a Lex scanner, and more precisely, a Flex scanner, to demonstrate the various interactions. A hand-written scanner is actually easier to interface with.

* + - 1. **Calc**++ **— C**++ **Calculator**

Of course the grammar is dedicated to arithmetics, a single expression, possibly preceded by variable assignments. An environment containing possibly predefined variables such as one and two, is exchanged with the parser. An example of valid input follows.

three := 3

seven := one + two \* three seven \* seven

#### Calc++ Parsing Driver

To support a pure interface with the parser (and the scanner) the technique of the “parsing context” is convenient: a structure containing all the data to exchange. Since, in addition to simply launch the parsing, there are several auxiliary tasks to execute (open the file for scanning, instantiate the parser etc.), we recommend transforming the simple parsing context structure into a fully blown *parsing driver* class.

The declaration of this driver class, in driver.hh, is as follows. The first part includes the CPP guard and imports the required standard library components, and the declaration of the parser class.

#ifndef DRIVER\_HH # define DRIVER\_HH # include <string> # include <map>

# include "parser.hh"

Then comes the declaration of the scanning function. Flex expects the signature of yylex to be defined in the macro YY\_DECL, and the C++ parser expects it to be declared. We can factor both as follows.

// Tell Flex the lexer’s prototype ... # define YY\_DECL \

yy::parser::symbol\_type yylex (driver& drv)

// ... and declare it for the parser’s sake. YY\_DECL;

The driver class is then declared with its most obvious members.

// Conducting the whole scanning and parsing of Calc++. class driver

{

public: driver ();

std::map<std::string, int> variables; int result;

The main routine is of course calling the parser.

// Run the parser on file F. Return 0 on success. int parse (const std::string& f);

// The name of the file being parsed. std::string file;

// Whether to generate parser debug traces. bool trace\_parsing;

To encapsulate the coordination with the Flex scanner, it is useful to have member functions to open and close the scanning phase.

// Handling the scanner. void scan\_begin (); void scan\_end ();

// Whether to generate scanner debug traces. bool trace\_scanning;

// The token’s location used by the scanner. yy::location location;

};

#endif // ! DRIVER\_HH

The implementation of the driver (driver.cc) is straightforward.

#include "driver.hh" #include "parser.hh"

driver::driver ()

: trace\_parsing (false), trace\_scanning (false)

{

variables["one"] = 1;

variables["two"] = 2;

}

The parse member function deserves some attention.

int

driver::parse (const std::string &f)

{

file = f; location.initialize (&file); scan\_begin ();

yy::parser parser (\*this); parser.set\_debug\_level (trace\_parsing); int res = parser.parse ();

scan\_end (); return res;

}

* + - 1. **Calc**++ **Parser**

The grammar file parser.yy starts by asking for the C++ deterministic parser skeleton, the creation of the parser header file. Because the C++ skeleton changed several times, it is safer to require the version you designed the grammar for.

skeleton "lalr1.cc" /\* -\*- C++ -\*- \*/ require "3.1"

defines

This example will use genuine C++ objects as semantic values, therefore, we require the variant-based interface. To make sure we properly use it, we enable assertions. To fully benefit from type-safety and more natural definition of “symbol”, we enable api.token.constructor.

define api.token.constructor define api.value.type variant define parse.assert

Then come the declarations/inclusions needed by the semantic values. Because the parser uses the parsing driver and reciprocally, both would like to include the header of the other, which is, of course, insane. This mutual dependency will be broken using forward decla- rations. Because the driver’s header needs detailed knowledge about the parser class (in particular its inner types), it is the parser’s header which will use a forward declaration of the driver. See [Section 3.7.14 [%code Summary], page 92](#_bookmark115).

code requires {

# include <string> class driver;

}

The driver is passed by reference to the parser and to the scanner. This provides a simple but effective pure interface, not relying on global variables.

// The parsing context. param { driver& drv }

Then we request location tracking.

locations

Use the following two directives to enable parser tracing and verbose error messages. How- ever, verbose error messages can contain incorrect information (see [Section 5.8.3 [LAC],](#_bookmark162) [page 121](#_bookmark162)).

define parse.trace define parse.error verbose

The code between ‘code {’ and ‘}’ is output in the \*.cc file; it needs detailed knowledge about the driver.

code {

# include "driver.hh"

}

The token numbered as 0 corresponds to end of file; the following line allows for nicer error messages referring to “end of file” instead of “$end”. Similarly user friendly names are provided for each symbol. To avoid name clashes in the generated files (see [Section 10.1.6.4](#_bookmark217) [[Calc++ Scanner], page 169](#_bookmark217)), prefix tokens with TOK\_ (see [Section 3.7.13 [api.token.prefix],](#_bookmark109) [page 86](#_bookmark109)).

define api.token.prefix {TOK\_} token

END 0 "end of file" ASSIGN ":="

MINUS "-"

PLUS "+"

STAR "\*"

SLASH "/" LPAREN "("

RPAREN ")"

;

Since we use variant-based semantic values, union is not used, and both type and token

expect genuine types, as opposed to type tags.

token <std::string> IDENTIFIER "identifier" token <int> NUMBER "number"

type <int> exp

No destructor is needed to enable memory deallocation during error recovery; the mem- ory, for strings for instance, will be reclaimed by the regular destructors. All the values are printed using their operator<< (see [Section 3.7.7 [Printing Semantic Values], page 79](#_bookmark98)).

printer { yyoutput << $$; } <\*>;

The grammar itself is straightforward (see [Section 2.4 [Location Tracking Calculator -](#_bookmark33)

[ltcalc], page 39](#_bookmark33)).



start unit;

unit: assignments exp { drv.result = $2; };

assignments:

empty {}

| assignments assignment {};

assignment:

"identifier" ":=" exp { drv.variables[$1] = $3; };

left "+" "-";

left "\*" "/"; exp:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | exp | "+" | exp | { | $$ | = | $1 | + | $3; | } |
| | | exp | "-" | exp | { | $$ | = | $1 | - | $3; | } |
| | | exp | "\*" | exp | { | $$ | = | $1 | \* | $3; | } |
| | | exp | "/" | exp | { | $$ | = | $1 | / | $3; | } |

| "(" exp ")" { std::swap ($$, $2); }

| "identifier" { $$ = drv.variables[$1]; }

| "number" { std::swap ($$, $1); };



Finally the error member function reports the errors.

void

yy::parser::error (const location\_type& l, const std::string& m)

{

std::cerr << l << ": " << m << ’\n’;

}

* + - 1. **Calc**++ **Scanner**

The Flex scanner first includes the driver declaration, then the parser’s to get the set of defined tokens.

{ /\* -\*- C++ -\*- \*/ # include <cerrno> # include <climits> # include <cstdlib> # include <string>

# include "driver.hh" # include "parser.hh"

// Work around an incompatibility in flex (at least versions

// 2.5.31 through 2.5.33): it generates code that does

// not conform to C89. See Debian bug 333231

// [<http://bugs.debian.org/cgi-bin/bugreport.cgi?bug=333231>.](http://bugs.debian.org/cgi-bin/bugreport.cgi?bug=333231) # undef yywrap

# define yywrap() 1

// Pacify warnings in yy\_init\_buffer (observed with Flex 2.6.4)

// and GCC 7.3.0.

#if defined GNUC && 7 <= GNUC

# pragma GCC diagnostic ignored "-Wnull-dereference" #endif

}

Because there is no #include-like feature we don’t need yywrap, we don’t need unput either, and we parse an actual file, this is not an interactive session with the user. Finally, we enable scanner tracing.

option noyywrap nounput batch debug noinput

Abbreviations allow for more readable rules.

id [a-zA-Z][a-zA-Z\_0-9]\* int [0-9]+

blank [ \t]

The following paragraph suffices to track locations accurately. Each time yylex is invoked, the begin position is moved onto the end position. Then when a pattern is matched, its width is added to the end column. When matching ends of lines, the end cursor is adjusted, and each time blanks are matched, the begin cursor is moved onto the end cursor to effectively ignore the blanks preceding tokens. Comments would be treated equally.

{

// Code run each time a pattern is matched.

# define YY\_USER\_ACTION loc.columns (yyleng); }



{

// A handy shortcut to the location held by the driver. yy::location& loc = drv.location;

// Code run each time yylex is called. loc.step ();

}

{blank}+ loc.step ();

[\n]+ loc.lines (yyleng); loc.step ();

The rules are simple. The driver is used to report errors.

"-" return yy::parser::make\_MINUS (loc); "+" return yy::parser::make\_PLUS (loc); "\*" return yy::parser::make\_STAR (loc); "/" return yy::parser::make\_SLASH (loc); "(" return yy::parser::make\_LPAREN (loc); ")" return yy::parser::make\_RPAREN (loc); ":=" return yy::parser::make\_ASSIGN (loc);

{int} { errno = 0;

long n = strtol (yytext, NULL, 10);

if (! (INT\_MIN <= n && n <= INT\_MAX && errno != ERANGE))

throw yy::parser::syntax\_error (loc, "integer is out of range: "

+ std::string(yytext)); return yy::parser::make\_NUMBER (n, loc);

}

{id} return yy::parser::make\_IDENTIFIER (yytext, loc);

. {

throw yy::parser::syntax\_error

(loc, "invalid character: " + std::string(yytext));

}

<<EOF>> return yy::parser::make\_END (loc);



Finally, because the scanner-related driver’s member-functions depend on the scanner’s data, it is simpler to implement them in this file.

void driver::scan\_begin ()

{

yy\_flex\_debug = trace\_scanning; if (file.empty () || file == "-")

yyin = stdin;

else if (!(yyin = fopen (file.c\_str (), "r")))

{

std::cerr << "cannot open " << file << ": " << strerror(errno) << ’\n’; exit (EXIT\_FAILURE);

}

}

void driver::scan\_end ()

{

fclose (yyin);

}

#### Calc++ Top Level

The top level file, calc++.cc, poses no problem.

#include <iostream> #include "driver.hh"

int

main (int argc, char \*argv[])

{

int res = 0; driver drv;

for (int i = 1; i < argc; ++i)

if (argv[i] == std::string ("-p")) drv.trace\_parsing = true;

else if (argv[i] == std::string ("-s")) drv.trace\_scanning = true;

else if (!drv.parse (argv[i])) std::cout << drv.result << ’\n’;

else

res = 1; return res;

}

## Java Parsers

#### Java Bison Interface

The Java parser skeletons are selected using the language "Java" directive or the -L java/--language=java option.

When generating a Java parser, bison *basename*.y will create a single Java source file named *basename*.java containing the parser implementation. Using a grammar file without a .y suffix is currently broken. The basename of the parser implementation file can be changed by the file-prefix directive or the -p/--name-prefix option. The entire parser implementation file name can be changed by the output directive or the -o/--output option. The parser implementation file contains a single class for the parser.

You can create documentation for generated parsers using Javadoc.

Contrary to C parsers, Java parsers do not use global variables; the state of the parser is always local to an instance of the parser class. Therefore, all Java parsers are “pure”, and the pure-parser and define api.pure directives do nothing when used in Java.

Push parsers are currently unsupported in Java and define api.push-pull have no effect.

GLR parsers are currently unsupported in Java. Do not use the glr-parser directive.

No header file can be generated for Java parsers. Do not use the defines directive or the -d/--defines options.

Currently, support for tracing is always compiled in. Thus the ‘define parse.trace’ and ‘token-table’ directives and the -t/--debug and -k/--token-table options have no effect. This may change in the future to eliminate unused code in the generated parser, so use ‘define parse.trace’ explicitly if needed. Also, in the future the token-table directive might enable a public interface to access the token names and codes.

Getting a “code too large” error from the Java compiler means the code hit the 64KB bytecode per method limitation of the Java class file. Try reducing the amount of code in

actions and static initializers; otherwise, report a bug so that the parser skeleton will be improved.

#### Java Semantic Values

There is no union directive in Java parsers. Instead, the semantic values’ types (class names) should be specified in the type or token directive:

type <Expression> expr assignment\_expr term factor type <Integer> number

By default, the semantic stack is declared to have Object members, which means that the class types you specify can be of any class. To improve the type safety of the parser, you can declare the common superclass of all the semantic values using the ‘ define api.value.type’ directive. For example, after the following declaration:

define api.value.type {ASTNode}

any type or token specifying a semantic type which is not a subclass of ASTNode, will cause a compile-time error.

Types used in the directives may be qualified with a package name. Primitive data types are accepted for Java version 1.5 or later. Note that in this case the autoboxing feature of Java 1.5 will be used. Generic types may not be used; this is due to a limitation in the implementation of Bison, and may change in future releases.

Java parsers do not support destructor, since the language adopts garbage collection.

The parser will try to hold references to semantic values for as little time as needed.

Java parsers do not support printer, as toString() can be used to print the semantic values. This however may change (in a backwards-compatible way) in future versions of Bison.

#### Java Location Values

When the directive locations is used, the Java parser supports location tracking, see [Section 3.5 [Tracking Locations], page 71](#_bookmark79). An auxiliary user-defined class defines a *position*, a single point in a file; Bison itself defines a class representing a *location*, a range composed of a pair of positions (possibly spanning several files). The location class is an inner class of the parser; the name is Location by default, and may also be renamed using define api.location.type {*class-name*}.

The location class treats the position as a completely opaque value. By default, the class name is Position, but this can be changed with define api.position.type {*class- name*}. This class must be supplied by the user.

###### Position begin Position end

[Instance Variable of Location] [Instance Variable of Location]

The first, inclusive, position of the range, and the first beyond.

Location (*Position loc*) [Constructor on Location]

Create a Location denoting an empty range located at a given point.

Location (*Position begin, Position end*)

Create a Location from the endpoints of the range.

[Constructor on Location]

String toString () [Method on Location]

Prints the range represented by the location. For this to work properly, the position class should override the equals and toString methods appropriately.

#### Java Parser Interface

The name of the generated parser class defaults to YYParser. The YY prefix may be changed using the name-prefix directive or the -p/--name-prefix option. Alternatively, use ‘define parser\_class\_name {*name*}’ to give a custom name to the class. The interface of this class is detailed below.

By default, the parser class has package visibility. A declaration ‘define public’ will change to public visibility. Remember that, according to the Java language specification, the name of the .java file should match the name of the class in this case. Similarly, you can use abstract, final and strictfp with the define declaration to add other modifiers to the parser class. A single ‘define annotations {*annotations*}’ directive can be used to add any number of annotations to the parser class.

The Java package name of the parser class can be specified using the ‘define package’ directive. The superclass and the implemented interfaces of the parser class can be specified with the define extends and ‘define implements’ directives.

The parser class defines an inner class, Location, that is used for location tracking (see [Section 10.2.3 [Java Location Values], page 173](#_bookmark223)), and a inner interface, Lexer (see [Section 10.2.5 [Java Scanner Interface], page 175](#_bookmark227)). Other than these inner class/interface, and the members described in the interface below, all the other members and fields are preceded with a yy or YY prefix to avoid clashes with user code.

The parser class can be extended using the parse-param directive. Each occurrence of the directive will add a protected final field to the parser class, and an argument to its constructor, which initialize them automatically.

YYParser (*lex\_param, . . . , parse\_param, . . .* ) [Constructor on YYParser]

Build a new parser object with embedded code lexer. There are no parameters, unless params and/or parse-params and/or lex-params are used.

Use code init for code added to the start of the constructor body. This is especially useful to initialize superclasses. Use ‘define init\_throws’ to specify any uncaught exceptions.

YYParser (*Lexer lexer, parse\_param, . . .* ) [Constructor on YYParser]

Build a new parser object using the specified scanner. There are no additional pa- rameters unless params and/or parse-params are used.

If the scanner is defined by code lexer, this constructor is declared protected and is called automatically with a scanner created with the correct params and/or lex-params.

Use code init for code added to the start of the constructor body. This is especially useful to initialize superclasses. Use ‘define init\_throws’ to specify any uncaught exceptions.

boolean parse () [Method on YYParser]

Run the syntactic analysis, and return true on success, false otherwise.

###### boolean getErrorVerbose ()

void setErrorVerbose (*boolean verbose*)

[Method on YYParser] [Method on YYParser]

Get or set the option to produce verbose error messages. These are only available with ‘define parse.error verbose’, which also turns on verbose error messages.

void yyerror (*String msg*)

void yyerror (*Position pos, String msg*)

void yyerror (*Location loc, String msg*)

[Method on YYParser] [Method on YYParser] [Method on YYParser]

Print an error message using the yyerror method of the scanner instance in use. The

Location and Position parameters are available only if location tracking is active.

boolean recovering () [Method on YYParser]

During the syntactic analysis, return true if recovering from a syntax error. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

###### java.io.PrintStream getDebugStream ()

void setDebugStream (*java.io.printStream o*)

[Method on YYParser] [Method on YYParser]

Get or set the stream used for tracing the parsing. It defaults to System.err.

###### int getDebugLevel ()

void setDebugLevel (*int l*)

[Method on YYParser] [Method on YYParser]

Get or set the tracing level. Currently its value is either 0, no trace, or nonzero, full tracing.

###### String bisonVersion String bisonSkeleton

[Constant of YYParser] [Constant of YYParser]

Identify the Bison version and skeleton used to generate this parser.

#### Java Scanner Interface

There are two possible ways to interface a Bison-generated Java parser with a scanner: the scanner may be defined by code lexer, or defined elsewhere. In either case, the scanner has to implement the Lexer inner interface of the parser class. This interface also contain constants for all user-defined token names and the predefined EOF token.

In the first case, the body of the scanner class is placed in code lexer blocks. If you want to pass parameters from the parser constructor to the scanner constructor, specify them with lex-param; they are passed before parse-params to the constructor.

In the second case, the scanner has to implement the Lexer interface, which is defined within the parser class (e.g., YYParser.Lexer). The constructor of the parser object will then accept an object implementing the interface; lex-param is not used in this case.

In both cases, the scanner has to implement the following methods.

void yyerror (*Location loc, String msg*) [Method on Lexer]

This method is defined by the user to emit an error message. The first parameter is omitted if location tracking is not active. Its type can be changed using define api.location.type {*class-name*}.

int yylex () [Method on Lexer]

Return the next token. Its type is the return value, its semantic value and location are saved and returned by the their methods in the interface.

Use ‘define lex\_throws’ to specify any uncaught exceptions. Default is

java.io.IOException.

###### Position getStartPos ()

Position getEndPos ()

[Method on Lexer] [Method on Lexer]

Return respectively the first position of the last token that yylex returned, and the first position beyond it. These methods are not needed unless location tracking is active.

The return type can be changed using define api.position.type {*class-name*}.

###### Object getLVal ()

Return the semantic value of the last token that yylex returned.

[Method on Lexer]

The return type can be changed using ‘define api.value.type {*class-name*}’.

#### Special Features for Use in Java Actions

The following special constructs can be uses in Java actions. Other analogous C action features are currently unavailable for Java.

Use ‘define throws’ to specify any uncaught exceptions from parser actions, and initial actions specified by initial-action.

$*n* [Variable]

The semantic value for the *n*th component of the current rule. This may not be assigned to. See [Section 10.2.2 [Java Semantic Values], page 173](#_bookmark222).

$<*typealt*>*n* [Variable]

Like $*n* but specifies a alternative type *typealt*. See [Section 10.2.2 [Java Semantic](#_bookmark222) [Values], page 173](#_bookmark222).

$$ [Variable]

The semantic value for the grouping made by the current rule. As a value, this is in the base type (Object or as specified by ‘ define api.value.type’) as in not cast to the declared subtype because casts are not allowed on the left-hand side of Java assignments. Use an explicit Java cast if the correct subtype is needed. See [Section 10.2.2 [Java Semantic Values], page 173](#_bookmark222).

$<*typealt*>$ [Variable]

Same as $$ since Java always allow assigning to the base type. Perhaps we should use this and $<>$ for the value and $$ for setting the value but there is currently no easy way to distinguish these constructs. See [Section 10.2.2 [Java Semantic Values],](#_bookmark222) [page 173](#_bookmark222).

@*n* [Variable]

The location information of the *n*th component of the current rule. This may not be assigned to. See [Section 10.2.3 [Java Location Values], page 173](#_bookmark223).

@$ [Variable]

The location information of the grouping made by the current rule. See [Section 10.2.3](#_bookmark223) [[Java Location Values], page 173](#_bookmark223).

return YYABORT ; [Statement]

Return immediately from the parser, indicating failure. See [Section 10.2.4 [Java](#_bookmark225) [Parser Interface], page 174](#_bookmark225).

return YYACCEPT ; [Statement]

Return immediately from the parser, indicating success. See [Section 10.2.4 [Java](#_bookmark225) [Parser Interface], page 174](#_bookmark225).

return YYERROR ; [Statement]

Start error recovery (without printing an error message). See [Chapter 6 [Error Re-](#_bookmark170) [covery], page 127](#_bookmark170).

boolean recovering () [Function]

Return whether error recovery is being done. In this state, the parser reads token until it reaches a known state, and then restarts normal operation. See [Chapter 6](#_bookmark170) [[Error Recovery], page 127](#_bookmark170).

void yyerror (*String msg*)

void yyerror (*Position loc, String msg*)

void yyerror (*Location loc, String msg*)

[Function] [Function] [Function]

Print an error message using the yyerror method of the scanner instance in use. The

Location and Position parameters are available only if location tracking is active.

#### Java Push Parser Interface

Normally, Bison generates a pull parser for Java. The following Bison declaration says that you want the parser to be a push parser (see [Section 3.7.13 [api.push-pull], page 86](#_bookmark109)):

define api.push-pull push

Most of the discussion about the Java pull Parser Interface, (see [Section 10.2.4 [Java](#_bookmark225) [Parser Interface], page 174](#_bookmark225)) applies to the push parser interface as well.

When generating a push parser, the method push\_parse is created with the following signature (depending on if locations are enabled).

void push\_parse (*int token, Object yylval*)

void push\_parse (*int token, Object yylval, Location*

*yyloc*)

void push\_parse (*int token, Object yylval, Position*

*yypos*)

[Method on YYParser] [Method on YYParser]

[Method on YYParser]

The primary difference with respect to a pull parser is that the parser method push\_ parse is invoked repeatedly to parse each token. This function is available if either the "%define api.push-pull push" or "%define api.push-pull both" declaration is used (see [Section 3.7.13 [api.push-pull], page 86](#_bookmark109)). The Location and Position parameters are avail- able only if location tracking is active.

The value returned by the push\_parse method is one of the following four constants:

YYABORT, YYACCEPT, YYERROR, or YYPUSH\_MORE. This new value, YYPUSH\_MORE, may be

returned if more input is required to finish parsing the grammar.

If api.push-pull is declared as both, then the generated parser class will also implement the parse method. This method’s body is a loop that repeatedly invokes the scanner and then passes the values obtained from the scanner to the push\_parse method.

There is one additional complication. Technically, the push parser does not need to know about the scanner (i.e. an object implementing the YYParser.Lexer interface), but it does need access to the yyerror method. Currently, the yyerror method is defined in the YYParser.Lexer interface. Hence, an implementation of that interface is still required in order to provide an implementation of yyerror. The current approach (and subject to change) is to require the YYParser constructor to be given an object implementing the YYParser.Lexer interface. This object need only implement the yyerror method; the other methods can be stubbed since they will never be invoked. The simplest way to do this is to add a trivial scanner implementation to your grammar file using whatever implementation of yyerror is desired. The following code sample shows a simple way to accomplish this.

code lexer

{

public Object getLVal () {return null;} public int yylex () {return 0;}

public void yyerror (String s) {System.err.println(s);}

}

#### Differences between C/C++ and Java Grammars

The different structure of the Java language forces several differences between C/C++ gram- mars, and grammars designed for Java parsers. This section summarizes these differences.

Java lacks a preprocessor, so the YYERROR, YYACCEPT, YYABORT symbols (see [Appendix A](#_bookmark242) [[Table of Symbols], page 189](#_bookmark242)) cannot obviously be macros. Instead, they should be preceded by return when they appear in an action. The actual definition of these symbols is opaque to the Bison grammar, and it might change in the future. The only meaningful operation that you can do, is to return them. See [Section 10.2.6 [Java](#_bookmark229) [Action Features], page 176](#_bookmark229).

*•*

Note that of these three symbols, only YYACCEPT and YYABORT will cause a return from the yyparse method1.

Java lacks unions, so union has no effect. Instead, semantic values have a common base type: Object or as specified by ‘ define api.value.type’. Angle brackets on token, type, $*n* and $$ specify subtypes rather than fields of an union. The type of

*•*

$$, even with angle brackets, is the base type since Java casts are not allow on the left-hand side of assignments. Also, $*n* and @*n* are not allowed on the left-hand side of assignments. See [Section 10.2.2 [Java Semantic Values], page 173](#_bookmark222), and [Section 10.2.6](#_bookmark229) [[Java Action Features], page 176](#_bookmark229).

* + - * The prologue declarations have a different meaning than in C/C++ code.

code imports

blocks are placed at the beginning of the Java source code. They may include copyright notices. For a package declarations, it is suggested to use ‘define package’ instead.

unqualified code

blocks are placed inside the parser class.

1 Java parsers include the actions in a separate method than yyparse in order to have an intuitive syntax that corresponds to these C macros.

code lexer

blocks, if specified, should include the implementation of the scanner. If there is no such block, the scanner can be any class that implements the ap- propriate interface (see [Section 10.2.5 [Java Scanner Interface], page 175](#_bookmark227)).

Other code blocks are not supported in Java parsers. In particular, { ...  } blocks should not be used and may give an error in future versions of Bison.

The epilogue has the same meaning as in C/C++ code and it can be used to define other classes used by the parser *outside* the parser class.

#### Java Declarations Summary

This summary only include declarations specific to Java or have special meaning when used in a Java parser.

###### language "Java"

Generate a Java class for the parser.

lex-param *{type name}*

[Directive]

[Directive]

A parameter for the lexer class defined by code lexer *only*, added as parameters to

the lexer constructor and the parser constructor that *creates* a lexer. Default is none. See [Section 10.2.5 [Java Scanner Interface], page 175](#_bookmark227).

name-prefix "*prefix*" [Directive]

The prefix of the parser class name *prefix*Parser if ‘define parser\_class\_name’ is not used. Default is YY. See [Section 10.2.1 [Java Bison Interface], page 172](#_bookmark220).

parse-param *{type name}*

[Directive]

A parameter for the parser class added as parameters to constructor(s) and as fields

initialized by the constructor(s). Default is none. See [Section 10.2.4 [Java Parser](#_bookmark225) [Interface], page 174](#_bookmark225).

token <*type*> *token . . .* [Directive]

Declare tokens. Note that the angle brackets enclose a Java *type*. See [Section 10.2.2](#_bookmark222) [[Java Semantic Values], page 173](#_bookmark222).

type <*type*> *nonterminal . . .* [Directive]

Declare the type of nonterminals. Note that the angle brackets enclose a Java *type*. See [Section 10.2.2 [Java Semantic Values], page 173](#_bookmark222).

code *{ code . . . }*

[Directive]

Code appended to the inside of the parser class. See [Section 10.2.8 [Java Differences],](#_bookmark232)

[page 178](#_bookmark232).

code imports *{ code . . . }*

[Directive]

Code inserted just after the package declaration. See [Section 10.2.8 [Java Differences],](#_bookmark232)

[page 178](#_bookmark232).

code init *{ code . . . }*

[Directive]

Code inserted at the beginning of the parser constructor body. See [Section 10.2.4](#_bookmark225)

[[Java Parser Interface], page 174](#_bookmark225).

code lexer *{ code . . . }*

[Directive]

Code added to the body of a inner lexer class within the parser class. See

[Section 10.2.5 [Java Scanner Interface], page 175](#_bookmark227).

*code . . .* [Directive]



Code (after the second ) appended to the end of the file, *outside* the parser class. See [Section 10.2.8 [Java Differences], page 178](#_bookmark232).



{ *code . . . %}*

[Directive]

Not supported. Use code imports instead. See [Section 10.2.8 [Java Differences],](#_bookmark232)

[page 178](#_bookmark232).

define abstract [Directive]

Whether the parser class is declared abstract. Default is false. See [Section 10.2.1](#_bookmark220) [[Java Bison Interface], page 172](#_bookmark220).

define annotations *{annotations}*

[Directive]

The Java annotations for the parser class. Default is none. See [Section 10.2.1 [Java](#_bookmark220)

[Bison Interface], page 172](#_bookmark220).

define extends *{superclass}*

[Directive]

The superclass of the parser class. Default is none. See [Section 10.2.1 [Java Bison](#_bookmark220)

[Interface], page 172](#_bookmark220).

define final [Directive]

Whether the parser class is declared final. Default is false. See [Section 10.2.1 [Java](#_bookmark220) [Bison Interface], page 172](#_bookmark220).

define implements *{interfaces}*

[Directive]

The implemented interfaces of the parser class, a comma-separated list. Default is

none. See [Section 10.2.1 [Java Bison Interface], page 172](#_bookmark220).

define init\_throws *{exceptions}*

[Directive]

The exceptions thrown by code init from the parser class constructor. Default is

none. See [Section 10.2.4 [Java Parser Interface], page 174](#_bookmark225).

define lex\_throws *{exceptions}*

[Directive]

The exceptions thrown by the yylex method of the lexer, a comma-separated list. De-

fault is java.io.IOException. See [Section 10.2.5 [Java Scanner Interface], page 175](#_bookmark227).

define api.location.type *{class}*

[Directive]

The name of the class used for locations (a range between two positions). This

class is generated as an inner class of the parser class by bison. Default is Location. Formerly named location\_type. See [Section 10.2.3 [Java Location Values], page 173](#_bookmark223).

define package *{package}*

[Directive]

The package to put the parser class in. Default is none. See [Section 10.2.1 [Java](#_bookmark220)

[Bison Interface], page 172](#_bookmark220).

###### define parser\_class\_name *{name}*

[Directive]

The name of the parser class. Default is YYParser or *name-prefix*Parser. See

[Section 10.2.1 [Java Bison Interface], page 172](#_bookmark220).

define api.position.type *{class}*

[Directive]

The name of the class used for positions. This class must be supplied by the user.

Default is Position. Formerly named position\_type. See [Section 10.2.3 [Java](#_bookmark223) [Location Values], page 173](#_bookmark223).

define public [Directive]

Whether the parser class is declared public. Default is false. See [Section 10.2.1 [Java](#_bookmark220) [Bison Interface], page 172](#_bookmark220).

define api.value.type *{class}*

[Directive]

The base type of semantic values. Default is Object. See [Section 10.2.2 [Java Se-](#_bookmark222)

[mantic Values], page 173](#_bookmark222).

define strictfp [Directive]

Whether the parser class is declared strictfp. Default is false. See [Section 10.2.1](#_bookmark220) [[Java Bison Interface], page 172](#_bookmark220).

define throws *{exceptions}*

[Directive]

The exceptions thrown by user-supplied parser actions and initial-action, a

comma-separated list. Default is none. See [Section 10.2.4 [Java Parser Interface],](#_bookmark225) [page 174](#_bookmark225).

# Frequently Asked Questions

Several questions about Bison come up occasionally. Here some of them are addressed.

## Memory Exhausted

My parser returns with error with a ‘memory exhausted’ message. What can I do?

This question is already addressed elsewhere, see [Section 3.3.3 [Recursive Rules], page 60](#_bookmark58).

## How Can I Reset the Parser

The following phenomenon has several symptoms, resulting in the following typical ques- tions:

I invoke yyparse several times, and on correct input it works properly; but when a parse error is found, all the other calls fail too. How can I reset the error flag of yyparse?

or

My parser includes support for an ‘#include’-like feature, in which case I run yyparse from yyparse. This fails although I did specify ‘ define api.pure full’.

These problems typically come not from Bison itself, but from Lex-generated scanners. Because these scanners use large buffers for speed, they might not notice a change of input file. As a demonstration, consider the following source file, first-line.l:

{

#include <stdio.h> #include <stdlib.h> }



.\*\n ECHO; return 1;



int

yyparse (char const \*file)

{

yyin = fopen (file, "r"); if (!yyin)

{

perror ("fopen"); exit (EXIT\_FAILURE);

}

/\* One token only. \*/ yylex ();

if (fclose (yyin) != 0)

{

perror ("fclose"); exit (EXIT\_FAILURE);

}

return 0;

}

int

main (void)

{

yyparse ("input"); yyparse ("input"); return 0;

}

If the file input contains

input:1: Hello, input:2: World!

then instead of getting the first line twice, you get:

$ *flex -ofirst-line.c first-line.l*

$ *gcc -ofirst-line first-line.c -ll*

$ *./first-line* input:1: Hello, input:2: World!

Therefore, whenever you change yyin, you must tell the Lex-generated scanner to discard its current buffer and switch to the new one. This depends upon your implementation of Lex; see its documentation for more. For Flex, it suffices to call ‘YY\_FLUSH\_BUFFER’ after each change to yyin. If your Flex-generated scanner needs to read from several input streams to handle features like include files, you might consider using Flex functions like ‘yy\_switch\_to\_buffer’ that manipulate multiple input buffers.

If your Flex-generated scanner uses start conditions (see Section “Start conditions” in *The Flex Manual*), you might also want to reset the scanner’s state, i.e., go back to the initial start condition, through a call to ‘BEGIN (0)’.

## Strings are Destroyed

My parser seems to destroy old strings, or maybe it loses track of them. Instead of reporting ‘"foo", "bar"’, it reports ‘"bar", "bar"’, or even ‘"foo\nbar", "bar"’.

This error is probably the single most frequent “bug report” sent to Bison lists, but is only concerned with a misunderstanding of the role of the scanner. Consider the following Lex code:

{

#include <stdio.h> char \*yylval = NULL; }



.\* yylval = yytext; return 1;

\n /\* IGNORE \*/



int main ()

{

/\* Similar to using $1, $2 in a Bison action. \*/ char \*fst = (yylex (), yylval);

char \*snd = (yylex (), yylval); printf ("\" s\", \"s\"\n", fst, snd); return 0;

}

If you compile and run this code, you get:

$ *flex -osplit-lines.c split-lines.l*

$ *gcc -osplit-lines split-lines.c -ll*

$ *printf ’one\ntwo\n’* | *./split-lines*

"one

two", "two"

this is because yytext is a buffer provided for *reading* in the action, but if you want to keep it, you have to duplicate it (e.g., using strdup). Note that the output may depend on how your implementation of Lex handles yytext. For instance, when given the Lex compatibility option -l (which triggers the option ‘ array’) Flex generates a different behavior:

$ *flex -l -osplit-lines.c split-lines.l*

$ *gcc -osplit-lines split-lines.c -ll*

$ *printf ’one\ntwo\n’* | *./split-lines*

"two", "two"

## Implementing Gotos/Loops

My simple calculator supports variables, assignments, and functions, but how can I implement gotos, or loops?

Although very pedagogical, the examples included in the document blur the distinction to make between the parser—whose job is to recover the structure of a text and to transmit it to subsequent modules of the program—and the processing (such as the execution) of this structure. This works well with so called straight line programs, i.e., precisely those that have a straightforward execution model: execute simple instructions one after the others.

If you want a richer model, you will probably need to use the parser to construct a tree that does represent the structure it has recovered; this tree is usually called the *abstract syntax tree*, or *AST* for short. Then, walking through this tree, traversing it in various ways, will enable treatments such as its execution or its translation, which will result in an interpreter or a compiler.

This topic is way beyond the scope of this manual, and the reader is invited to consult the dedicated literature.

## Multiple start-symbols

I have several closely related grammars, and I would like to share their im- plementations. In fact, I could use a single grammar but with multiple entry points.

Bison does not support multiple start-symbols, but there is a very simple means to simulate them. If foo and bar are the two pseudo start-symbols, then introduce two new tokens, say START\_FOO and START\_BAR, and use them as switches from the real start-symbol:

token START\_FOO START\_BAR;

start start; start:

START\_FOO foo

| START\_BAR bar;

These tokens prevents the introduction of new conflicts. As far as the parser goes, that is all that is needed.

Now the difficult part is ensuring that the scanner will send these tokens first. If your scanner is hand-written, that should be straightforward. If your scanner is generated by Lex, them there is simple means to do it: recall that anything between ‘{ ...  }’ after the first is copied verbatim in the top of the generated yylex function. Make sure a variable start\_token is available in the scanner (e.g., a global variable or using lex-param etc.), and use the following:



/\* Prologue. \*/



{

if (start\_token)

{

int t = start\_token; start\_token = 0; return t;

}

}

/\* The rules. \*/

## Secure? Conform?

Is Bison secure? Does it conform to POSIX?

If you’re looking for a guarantee or certification, we don’t provide it. However, Bison is intended to be a reliable program that conforms to the POSIX specification for Yacc. If you run into problems, please send us a bug report.

## I can’t build Bison

I can’t build Bison because make complains that msgfmt is not found. What should I do?

Like most GNU packages with internationalization support, that feature is turned on by default. If you have problems building in the po subdirectory, it indicates that your system’s internationalization support is lacking. You can re-configure Bison with --disable-nls to turn off this support, or you can install GNU gettext from [https://ftp.gnu.org/gnu/](https://ftp.gnu.org/gnu/gettext/) [gettext/](https://ftp.gnu.org/gnu/gettext/) and re-configure Bison. See the file ABOUT-NLS for more information.

## Where can I find help?

I’m having trouble using Bison. Where can I find help?

First, read this fine manual. Beyond that, you can send mail to [help-bison@gnu.org](mailto:help-bison@gnu.org). This mailing list is intended to be populated with people who are willing to answer questions about using and installing Bison. Please keep in mind that (most of) the people on the list have aspects of their lives which are not related to Bison (!), so you may not receive an answer to your question right away. This can be frustrating, but please try not to honk them off; remember that any help they provide is purely voluntary and out of the kindness of their hearts.

## Bug Reports

I found a bug. What should I include in the bug report?

Before you send a bug report, make sure you are using the latest version. Check [https://](https://ftp.gnu.org/pub/gnu/bison/) [ftp.gnu.org/pub/gnu/bison/](https://ftp.gnu.org/pub/gnu/bison/) or one of its mirrors. Be sure to include the version number in your bug report. If the bug is present in the latest version but not in a previous version, try to determine the most recent version which did not contain the bug.

If the bug is parser-related, you should include the smallest grammar you can which demonstrates the bug. The grammar file should also be complete (i.e., I should be able to run it through Bison without having to edit or add anything). The smaller and simpler the grammar, the easier it will be to fix the bug.

Include information about your compilation environment, including your operating sys- tem’s name and version and your compiler’s name and version. If you have trouble compil- ing, you should also include a transcript of the build session, starting with the invocation of ‘configure’. Depending on the nature of the bug, you may be asked to send additional files as well (such as config.h or config.cache).

Patches are most welcome, but not required. That is, do not hesitate to send a bug report just because you cannot provide a fix.

Send bug reports to [bug-bison@gnu.org](mailto:bug-bison@gnu.org).

## More Languages

Will Bison ever have C++ and Java support? How about *insert your favorite language here*?

C++ and Java support is there now, and is documented. We’d love to add other languages; contributions are welcome.

## Beta Testing

What is involved in being a beta tester?

It’s not terribly involved. Basically, you would download a test release, compile it, and use it to build and run a parser or two. After that, you would submit either a bug report or a message saying that everything is okay. It is important to report successes as well as failures because test releases eventually become mainstream releases, but only if they are adequately tested. If no one tests, development is essentially halted.

Beta testers are particularly needed for operating systems to which the developers do not have easy access. They currently have easy access to recent GNU/Linux and Solaris versions. Reports about other operating systems are especially welcome.

## Mailing Lists

How do I join the help-bison and bug-bison mailing lists?

See <http://lists.gnu.org/>.

# Appendix A Bison Symbols

@$ [Variable]

In an action, the location of the left-hand side of the rule. See [Section 3.5 [Tracking](#_bookmark79) [Locations], page 71](#_bookmark79).

@*n* [Variable]

@*n* [Symbol]

In an action, the location of the *n*-th symbol of the right-hand side of the rule. See [Section 3.5 [Tracking Locations], page 71](#_bookmark79).

In a grammar, the Bison-generated nonterminal symbol for a mid-rule action with a semantical value. See [Section 3.4.8.3 [Mid-Rule Action Translation], page 68](#_bookmark76).

@*name* @[*name*]

[Variable] [Variable]

$@*n*

###### $$

$*n*

In an action, the location of a symbol addressed by *name*. See [Section 3.5 [Tracking](#_bookmark79) [Locations], page 71](#_bookmark79).

[Symbol] In a grammar, the Bison-generated nonterminal symbol for a mid-rule action with no semantical value. See [Section 3.4.8.3 [Mid-Rule Action Translation], page 68](#_bookmark76).

[Variable] In an action, the semantic value of the left-hand side of the rule. See [Section 3.4.6](#_bookmark68) [[Actions], page 64](#_bookmark68).

[Variable] In an action, the semantic value of the *n*-th symbol of the right-hand side of the rule. See [Section 3.4.6 [Actions], page 64](#_bookmark68).

$*name*

$[*name*]

[Variable] [Variable]

In an action, the semantic value of a symbol addressed by *name*. See [Section 3.4.6](#_bookmark68) [[Actions], page 64](#_bookmark68).

[Delimiter] Delimiter used to separate the grammar rule section from the Bison declarations section or the epilogue. See [Section 1.9 [The Overall Layout of a Bison Grammar],](#_bookmark20) [page 29](#_bookmark20).



{*code *} [Delimiter]

All code listed between ‘{’ and ‘}’ is copied verbatim to the parser implementation file. Such code forms the prologue of the grammar file. See [Section 3.1 [Outline of a](#_bookmark45) [Bison Grammar], page 51](#_bookmark45).

?{*expression*} [Directive]

Predicate actions. This is a type of action clause that may appear in rules. The expression is evaluated, and if false, causes a syntax error. In GLR parsers during nondeterministic operation, this silently causes an alternative parse to die. During deterministic operation, it is the same as the effect of YYERROR. See [Section 1.5.4](#_bookmark16) [[Semantic Predicates], page 26](#_bookmark16).

/\* *. . . \*/*

// *. . .*

Comments, as in C/C++.

###### :

[Construct] [Construct]

[Delimiter]

###### ;

|

<\*>

<>

Separates a rule’s result from its components. See [Section 3.3 [Syntax of Grammar](#_bookmark55) [Rules], page 59](#_bookmark55).

[Delimiter]

Terminates a rule. See [Section 3.3 [Syntax of Grammar Rules], page 59](#_bookmark55).

[Delimiter] Separates alternate rules for the same result nonterminal. See [Section 3.3 [Syntax of](#_bookmark55) [Grammar Rules], page 59](#_bookmark55).

[Directive]

Used to define a default tagged destructor or default tagged printer.

See [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95).

[Directive]

Used to define a default tagless destructor or default tagless printer.

See [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95).

$accept [Symbol]

The predefined nonterminal whose only rule is ‘$accept: *start* $end’, where *start* is the start symbol. See [Section 3.7.9 [The Start-Symbol], page 81](#_bookmark101). It cannot be used in the grammar.

code *{code}*

code *qualifier {code}*

[Directive] [Directive]

Insert *code* verbatim into the output parser source at the default location or at the

location specified by *qualifier*. See [Section 3.7.14 [%code Summary], page 92](#_bookmark115).

debug [Directive]

Equip the parser for debugging. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

define *variable *define *variable value *define *variable value*

*{ }*

define *variable* "*value*"

[Directive] [Directive] [Directive] [Directive]

Define a variable to adjust Bison’s behavior. See [Section 3.7.13 [%define Summary],](#_bookmark109) [page 86](#_bookmark109).

defines [Directive]

Bison declaration to create a parser header file, which is usually meant for the scanner. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

defines *defines-file* [Directive]

Same as above, but save in the file *defines-file*. See [Section 3.7.12 [Decl Summary],](#_bookmark105) [page 83](#_bookmark105).

destructor [Directive]

Specify how the parser should reclaim the memory associated to discarded symbols. See [Section 3.7.6 [Freeing Discarded Symbols], page 77](#_bookmark95).

dprec [Directive]

Bison declaration to assign a precedence to a rule that is used at parse time to resolve reduce/reduce conflicts. See [Section 1.5 [Writing GLR Parsers], page 20](#_bookmark9).

empty [Directive]

###### $end

Bison declaration to declare make explicit that a rule has an empty right-hand side. See [Section 3.3.2 [Empty Rules], page 60](#_bookmark57).

[Symbol] The predefined token marking the end of the token stream. It cannot be used in the grammar.

error [Symbol]

A token name reserved for error recovery. This token may be used in grammar rules so as to allow the Bison parser to recognize an error in the grammar without halting the process. In effect, a sentence containing an error may be recognized as valid. On a syntax error, the token error becomes the current lookahead token. Actions corresponding to error are then executed, and the lookahead token is reset to the token that originally caused the violation. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

error-verbose [Directive]

An obsolete directive standing for ‘define parse.error verbose’ (see [Section 4.7](#_bookmark134) [[The Error Reporting Function yyerror], page 102](#_bookmark134)).

file-prefix "*prefix*" [Directive]

Bison declaration to set the prefix of the output files. See [Section 3.7.12 [Decl Sum-](#_bookmark105) [mary], page 83](#_bookmark105).

glr-parser [Directive]

Bison declaration to produce a GLR parser. See [Section 1.5 [Writing GLR Parsers],](#_bookmark9) [page 20](#_bookmark9).

initial-action [Directive]

Run user code before parsing. See [Section 3.7.5 [Performing Actions before Parsing],](#_bookmark94) [page 77](#_bookmark94).

language [Directive]

Specify the programming language for the generated parser. See [Section 3.7.12 [Decl](#_bookmark105) [Summary], page 83](#_bookmark105).

left [Directive]

Bison declaration to assign precedence and left associativity to token(s). See [Section 3.7.3 [Operator Precedence], page 76](#_bookmark91).

lex-param *{argument-declaration} . . .*

[Directive]

Bison declaration to specifying additional arguments that yylex should accept. See

[Section 4.6.4 [Calling Conventions for Pure Parsers], page 101](#_bookmark132).

merge [Directive]

Bison declaration to assign a merging function to a rule. If there is a reduce/reduce conflict with a rule having the same merging function, the function is applied to the two semantic values to get a single result. See [Section 1.5 [Writing GLR Parsers],](#_bookmark9) [page 20](#_bookmark9).

name-prefix "*prefix*" [Directive]

Obsoleted by the define variable api.prefix (see [Section 3.8 [Multiple Parsers in](#_bookmark118) [the Same Program], page 94](#_bookmark118)).

Rename the external symbols (variables and functions) used in the parser so that they start with *prefix* instead of ‘yy’. Contrary to api.prefix, do no rename types and macros.

The precise list of symbols renamed in C parsers is yyparse, yylex, yyerror, yynerrs, yylval, yychar, yydebug, and (if locations are used) yylloc. If you use a push parser, yypush\_parse, yypull\_parse, yypstate, yypstate\_new and yypstate\_delete will also be renamed. For example, if you use ‘ name-prefix "c\_"’, the names become c\_parse, c\_lex, and so on. For C++ parsers, see the define api.namespace documentation in this section.

no-lines [Directive]

Bison declaration to avoid generating #line directives in the parser implementation file. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

nonassoc [Directive]

Bison declaration to assign precedence and nonassociativity to token(s). See [Section 3.7.3 [Operator Precedence], page 76](#_bookmark91).

output "*file*" [Directive]

Bison declaration to set the name of the parser implementation file. See [Section 3.7.12](#_bookmark105) [[Decl Summary], page 83](#_bookmark105).

param *{argument-declaration} . . .*

[Directive]

Bison declaration to specify additional arguments that both yylex and yyparse

should accept. See [Section 4.1 [The Parser Function yyparse], page 97](#_bookmark120).

parse-param *{argument-declaration} . . .*

[Directive]

Bison declaration to specify additional arguments that yyparse should accept. See

[Section 4.1 [The Parser Function yyparse], page 97](#_bookmark120).

prec [Directive]

Bison declaration to assign a precedence to a specific rule. See [Section 5.4 [Context-](#_bookmark149) [Dependent Precedence], page 112](#_bookmark149).

precedence [Directive]

Bison declaration to assign precedence to token(s), but no associativity See [Section 3.7.3 [Operator Precedence], page 76](#_bookmark91).

pure-parser [Directive]

Deprecated version of ‘define api.pure’ (see [Section 3.7.13 [api.pure], page 86](#_bookmark109)), for which Bison is more careful to warn about unreasonable usage.

require "*version*" [Directive]

Require version *version* or higher of Bison. See [Section 3.7.1 [Require a Version of](#_bookmark88) [Bison], page 75](#_bookmark88).

right [Directive]

Bison declaration to assign precedence and right associativity to token(s). See [Section 3.7.3 [Operator Precedence], page 76](#_bookmark91).

skeleton [Directive]

Specify the skeleton to use; usually for development. See [Section 3.7.12 [Decl Sum-](#_bookmark105) [mary], page 83](#_bookmark105).

start [Directive]

Bison declaration to specify the start symbol. See [Section 3.7.9 [The Start-Symbol],](#_bookmark101) [page 81](#_bookmark101).

token [Directive]

Bison declaration to declare token(s) without specifying precedence. See [Section 3.7.2](#_bookmark89) [[Token Type Names], page 75](#_bookmark89).

token-table [Directive]

Bison declaration to include a token name table in the parser implementation file. See [Section 3.7.12 [Decl Summary], page 83](#_bookmark105).

type [Directive]

Bison declaration to declare nonterminals. See [Section 3.7.4 [Nonterminal Symbols],](#_bookmark93) [page 77](#_bookmark93).

$undefined [Symbol]

The predefined token onto which all undefined values returned by yylex are mapped. It cannot be used in the grammar, rather, use error.

union [Directive]

Bison declaration to specify several possible data types for semantic values. See [Section 3.4.4 [The Union Declaration], page 63](#_bookmark66).

YYABORT [Macro]

Macro to pretend that an unrecoverable syntax error has occurred, by making yyparse return 1 immediately. The error reporting function yyerror is not called. See [Section 4.1 [The Parser Function yyparse], page 97](#_bookmark120).

For Java parsers, this functionality is invoked using return YYABORT; instead.

YYACCEPT [Macro]

Macro to pretend that a complete utterance of the language has been read, by mak- ing yyparse return 0 immediately. See [Section 4.1 [The Parser Function yyparse],](#_bookmark120) [page 97](#_bookmark120).

For Java parsers, this functionality is invoked using return YYACCEPT; instead.

YYBACKUP [Macro]

Macro to discard a value from the parser stack and fake a lookahead token. See [Section 4.8 [Special Features for Use in Actions], page 103](#_bookmark136).

yychar [Variable]

External integer variable that contains the integer value of the lookahead token. (In a pure parser, it is a local variable within yyparse.) Error-recovery rule actions may examine this variable. See [Section 4.8 [Special Features for Use in Actions], page 103](#_bookmark136).

yyclearin [Variable]

Macro used in error-recovery rule actions. It clears the previous lookahead token. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

YYDEBUG [Macro]

Macro to define to equip the parser with tracing code. See [Section 8.4 [Tracing Your](#_bookmark188) [Parser], page 143](#_bookmark188).

yydebug [Variable]

External integer variable set to zero by default. If yydebug is given a nonzero value, the parser will output information on input symbols and parser action. See [Section 8.4](#_bookmark188) [[Tracing Your Parser], page 143](#_bookmark188).

yyerrok [Macro]

Macro to cause parser to recover immediately to its normal mode after a syntax error. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

YYERROR [Macro]

Cause an immediate syntax error. This statement initiates error recovery just as if the parser itself had detected an error; however, it does not call yyerror, and does not print any message. If you want to print an error message, call yyerror explicitly before the ‘YYERROR;’ statement. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

For Java parsers, this functionality is invoked using return YYERROR; instead.

yyerror [Function]

User-supplied function to be called by yyparse on error. See [Section 4.7 [The Error](#_bookmark134) [Reporting Function yyerror], page 102](#_bookmark134).

YYERROR\_VERBOSE [Macro]

An obsolete macro used in the yacc.c skeleton, that you define with #define in the prologue to request verbose, specific error message strings when yyerror is called. It doesn’t matter what definition you use for YYERROR\_VERBOSE, just whether you define it. Using ‘define parse.error verbose’ is preferred (see [Section 4.7 [The](#_bookmark134) [Error Reporting Function yyerror], page 102](#_bookmark134)).

YYFPRINTF [Macro]

Macro used to output run-time traces. See [Section 8.4.1 [Enabling Traces], page 143](#_bookmark189).

YYINITDEPTH [Macro]

Macro for specifying the initial size of the parser stack. See [Section 5.10 [Memory](#_bookmark168) [Management], page 124](#_bookmark168).

yylex [Function]

User-supplied lexical analyzer function, called with no arguments to get the next token. See [Section 4.6 [The Lexical Analyzer Function yylex], page 99](#_bookmark126).

yylloc [Variable]

External variable in which yylex should place the line and column numbers associated with a token. (In a pure parser, it is a local variable within yyparse, and its address is passed to yylex.) You can ignore this variable if you don’t use the ‘@’ feature in the grammar actions. See [Section 4.6.3 [Textual Locations of Tokens], page 101](#_bookmark131). In semantic actions, it stores the location of the lookahead token. See [Section 3.5.2](#_bookmark81) [[Actions and Locations], page 71](#_bookmark81).

YYLTYPE [Type]

Data type of yylloc; by default, a structure with four members. See [Section 3.5.1](#_bookmark80) [[Data Types of Locations], page 71](#_bookmark80).

yylval [Variable]

External variable in which yylex should place the semantic value associated with a token. (In a pure parser, it is a local variable within yyparse, and its address is passed to yylex.) See [Section 4.6.2 [Semantic Values of Tokens], page 100](#_bookmark129). In semantic actions, it stores the semantic value of the lookahead token. See [Section 3.4.6](#_bookmark68) [[Actions], page 64](#_bookmark68).

YYMAXDEPTH [Macro]

Macro for specifying the maximum size of the parser stack. See [Section 5.10 [Memory](#_bookmark168) [Management], page 124](#_bookmark168).

yynerrs [Variable]

Global variable which Bison increments each time it reports a syntax error. (In a pure parser, it is a local variable within yyparse. In a pure push parser, it is a member of yypstate.) See [Section 4.7 [The Error Reporting Function yyerror], page 102](#_bookmark134).

yyparse [Function]

The parser function produced by Bison; call this function to start parsing. See [Section 4.1 [The Parser Function yyparse], page 97](#_bookmark120).

YYPRINT [Macro]

Macro used to output token semantic values. For yacc.c only. Obsoleted by

printer. See [Section 8.4.3 [The YYPRINT Macro], page 147](#_bookmark193).

yypstate\_delete [Function]

The function to delete a parser instance, produced by Bison in push mode; call this function to delete the memory associated with a parser. See [Section 4.5 [The Parser](#_bookmark125) [Delete Function yypstate\_delete], page 99](#_bookmark125). Does nothing when called with a null pointer.

yypstate\_new [Function]

The function to create a parser instance, produced by Bison in push mode; call this function to create a new parser. See [Section 4.4 [The Parser Create Function](#_bookmark124) [yypstate\_new], page 98](#_bookmark124).

yypull\_parse [Function]

The parser function produced by Bison in push mode; call this function to parse the rest of the input stream. See [Section 4.3 [The Pull Parser Function yypull\_parse],](#_bookmark123) [page 98](#_bookmark123).

yypush\_parse [Function]

The parser function produced by Bison in push mode; call this function to parse a single token. See [Section 4.2 [The Push Parser Function yypush\_parse], page 98](#_bookmark122).

YYRECOVERING [Macro]

The expression YYRECOVERING () yields 1 when the parser is recovering from a syntax error, and 0 otherwise. See [Section 4.8 [Special Features for Use in Actions], page 103](#_bookmark136).

YYSTACK\_USE\_ALLOCA [Macro]

Macro used to control the use of alloca when the deterministic parser in C needs to extend its stacks. If defined to 0, the parser will use malloc to extend its stacks. If defined to 1, the parser will use alloca. Values other than 0 and 1 are reserved for future Bison extensions. If not defined, YYSTACK\_USE\_ALLOCA defaults to 0.

In the all-too-common case where your code may run on a host with a limited stack and with unreliable stack-overflow checking, you should set YYMAXDEPTH to a value that cannot possibly result in unchecked stack overflow on any of your target hosts when alloca is called. You can inspect the code that Bison generates in order to determine the proper numeric values. This will require some expertise in low-level implementation details.

YYSTYPE [Type]

Deprecated in favor of the define variable api.value.type. Data type of semantic values; int by default. See [Section 3.4.1 [Data Types of Semantic Values], page 61](#_bookmark61).

# Appendix B Glossary

Accepting state

A state whose only action is the accept action. The accepting state is thus a consistent state. See [Section 8.1 [Understanding Your Parser], page 133](#_bookmark178).

Backus-Naur Form (BNF; also called “Backus Normal Form”)

Formal method of specifying context-free grammars originally proposed by John Backus, and slightly improved by Peter Naur in his 1960-01-02 committee doc- ument contributing to what became the Algol 60 report. See [Section 1.1 [Lan-](#_bookmark4) [guages and Context-Free Grammars], page 17](#_bookmark4).

Consistent state

A state containing only one possible action. See [Section 5.8.2 [Default Reduc-](#_bookmark159) [tions], page 119](#_bookmark159).

Context-free grammars

Grammars specified as rules that can be applied regardless of context. Thus, if there is a rule which says that an integer can be used as an expression, integers are allowed *anywhere* an expression is permitted. See [Section 1.1 [Languages](#_bookmark4) [and Context-Free Grammars], page 17](#_bookmark4).

Default reduction

The reduction that a parser should perform if the current parser state contains no other action for the lookahead token. In permitted parser states, Bison declares the reduction with the largest lookahead set to be the default reduc- tion and removes that lookahead set. See [Section 5.8.2 [Default Reductions],](#_bookmark159) [page 119](#_bookmark159).

Defaulted state

A consistent state with a default reduction. See [Section 5.8.2 [Default Reduc-](#_bookmark159) [tions], page 119](#_bookmark159).

Dynamic allocation

Allocation of memory that occurs during execution, rather than at compile time or on entry to a function.

Empty string

Analogous to the empty set in set theory, the empty string is a character string of length zero.

Finite-state stack machine

A “machine” that has discrete states in which it is said to exist at each instant in time. As input to the machine is processed, the machine moves from state to state as specified by the logic of the machine. In the case of the parser, the input is the language being parsed, and the states correspond to various stages in the grammar rules. See [Chapter 5 [The Bison Parser Algorithm], page 107](#_bookmark140).

Generalized LR (GLR)

A parsing algorithm that can handle all context-free grammars, including those that are not LR(1). It resolves situations that Bison’s deterministic parsing algorithm cannot by effectively splitting off multiple parsers, trying all possible

parsers, and discarding those that fail in the light of additional right context. See [Section 5.9 [Generalized LR Parsing], page 123](#_bookmark166).

Grouping A language construct that is (in general) grammatically divisible; for example, ‘expression’ or ‘declaration’ in C. See [Section 1.1 [Languages and Context-Free](#_bookmark4) [Grammars], page 17](#_bookmark4).

IELR(1) (Inadequacy Elimination LR(1))

A minimal LR(1) parser table construction algorithm. That is, given any context-free grammar, IELR(1) generates parser tables with the full language- recognition power of canonical LR(1) but with nearly the same number of parser states as LALR(1). This reduction in parser states is often an order of mag- nitude. More importantly, because canonical LR(1)’s extra parser states may contain duplicate conflicts in the case of non-LR(1) grammars, the number of conflicts for IELR(1) is often an order of magnitude less as well. This can sig- nificantly reduce the complexity of developing a grammar. See [Section 5.8.1](#_bookmark157)  [[LR Table Construction], page 118](#_bookmark157).

Infix operator

An arithmetic operator that is placed between the operands on which it per- forms some operation.

Input stream

A continuous flow of data between devices or programs.

LAC (Lookahead Correction)

A parsing mechanism that fixes the problem of delayed syntax error detec- tion, which is caused by LR state merging, default reductions, and the use of nonassoc. Delayed syntax error detection results in unexpected semantic actions, initiation of error recovery in the wrong syntactic context, and an incor- rect list of expected tokens in a verbose syntax error message. See [Section 5.8.3](#_bookmark162) [[LAC], page 121](#_bookmark162).

Language construct

One of the typical usage schemas of the language. For example, one of the constructs of the C language is the if statement. See [Section 1.1 [Languages](#_bookmark4) [and Context-Free Grammars], page 17](#_bookmark4).

Left associativity

Operators having left associativity are analyzed from left to right: ‘a+b+c’ first computes ‘a+b’ and then combines with ‘c’. See [Section 5.3 [Operator](#_bookmark145) [Precedence], page 109](#_bookmark145).

Left recursion

A rule whose result symbol is also its first component symbol; for example, ‘expseq1 : expseq1 ’,’ exp;’. See [Section 3.3.3 [Recursive Rules], page 60](#_bookmark58).

Left-to-right parsing

Parsing a sentence of a language by analyzing it token by token from left to right. See [Chapter 5 [The Bison Parser Algorithm], page 107](#_bookmark140).

Lexical analyzer (scanner)

A function that reads an input stream and returns tokens one by one. See [Section 4.6 [The Lexical Analyzer Function yylex], page 99](#_bookmark126).

Lexical tie-in

A flag, set by actions in the grammar rules, which alters the way tokens are parsed. See [Section 7.2 [Lexical Tie-ins], page 130](#_bookmark175).

Literal string token

A token which consists of two or more fixed characters. See [Section 3.2 [Sym-](#_bookmark52) [bols], page 57](#_bookmark52).

Lookahead token

A token already read but not yet shifted. See [Section 5.1 [Lookahead Tokens],](#_bookmark141) [page 107](#_bookmark141).

LALR(1) The class of context-free grammars that Bison (like most other parser gener- ators) can handle by default; a subset of LR(1). See [Section 5.7 [Mysterious](#_bookmark154) [Conflicts], page 116](#_bookmark154).

LR(1) The class of context-free grammars in which at most one token of lookahead is needed to disambiguate the parsing of any piece of input.

Nonterminal symbol

A grammar symbol standing for a grammatical construct that can be expressed through rules in terms of smaller constructs; in other words, a construct that is not a token. See [Section 3.2 [Symbols], page 57](#_bookmark52).

Parser A function that recognizes valid sentences of a language by analyzing the syntax structure of a set of tokens passed to it from a lexical analyzer.

Postfix operator

An arithmetic operator that is placed after the operands upon which it performs some operation.

Reduction Replacing a string of nonterminals and/or terminals with a single nonterminal, according to a grammar rule. See [Chapter 5 [The Bison Parser Algorithm],](#_bookmark140) [page 107](#_bookmark140).

Reentrant A reentrant subprogram is a subprogram which can be in invoked any number of times in parallel, without interference between the various invocations. See [Section 3.7.10 [A Pure (Reentrant) Parser], page 81](#_bookmark102).

Reverse Polish Notation

A language in which all operators are postfix operators.

Right recursion

A rule whose result symbol is also its last component symbol; for example, ‘expseq1: exp ’,’ expseq1;’. See [Section 3.3.3 [Recursive Rules], page 60](#_bookmark58).

Semantics In computer languages, the semantics are specified by the actions taken for each instance of the language, i.e., the meaning of each statement. See [Section 3.4](#_bookmark60) [[Defining Language Semantics], page 61](#_bookmark60).

Shift A parser is said to shift when it makes the choice of analyzing further input from the stream rather than reducing immediately some already-recognized rule. See [Chapter 5 [The Bison Parser Algorithm], page 107](#_bookmark140).

Single-character literal

A single character that is recognized and interpreted as is. See [Section 1.2](#_bookmark6) [[From Formal Rules to Bison Input], page 18](#_bookmark6).

Start symbol

The nonterminal symbol that stands for a complete valid utterance in the lan- guage being parsed. The start symbol is usually listed as the first nontermi- nal symbol in a language specification. See [Section 3.7.9 [The Start-Symbol],](#_bookmark101) [page 81](#_bookmark101).

Symbol table

A data structure where symbol names and associated data are stored during parsing to allow for recognition and use of existing information in repeated uses of a symbol. See [Section 2.5 [Multi-function Calc], page 42](#_bookmark37).

Syntax error

An error encountered during parsing of an input stream due to invalid syntax. See [Chapter 6 [Error Recovery], page 127](#_bookmark170).

Token A basic, grammatically indivisible unit of a language. The symbol that describes a token in the grammar is a terminal symbol. The input of the Bison parser is a stream of tokens which comes from the lexical analyzer. See [Section 3.2](#_bookmark52) [[Symbols], page 57](#_bookmark52).

Terminal symbol

A grammar symbol that has no rules in the grammar and therefore is gram- matically indivisible. The piece of text it represents is a token. See [Section 1.1](#_bookmark4) [[Languages and Context-Free Grammars], page 17](#_bookmark4).

Unreachable state

A parser state to which there does not exist a sequence of transitions from the parser’s start state. A state can become unreachable during conflict resolution. See [Section 5.8.4 [Unreachable States], page 122](#_bookmark164).

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# Index of Terms

## $

$$ *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [64](#_bookmark67), [103](#_bookmark135), [176](#_bookmark228), [189](#_bookmark242)

$<*typealt*>$ [103](#_bookmark135), [176](#_bookmark228)

$<*typealt*>*n* [103](#_bookmark135), [176](#_bookmark228)

$@*n* [68](#_bookmark75), [189](#_bookmark242)

$[*name*] [64](#_bookmark67), [189](#_bookmark242)

$accept [190](#_bookmark243)

$end [191](#_bookmark244)

$*n* [64](#_bookmark67), [103](#_bookmark135), [176](#_bookmark228), [189](#_bookmark242)

$*name* [64](#_bookmark67), [189](#_bookmark242)

$undefined [193](#_bookmark246)

## %

*. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [180](#_bookmark234), [189](#_bookmark242)



? *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [26](#_bookmark15)

?{*expression*} [189](#_bookmark242)

{ *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [180](#_bookmark234)

{*code *} [189](#_bookmark242)

code [52](#_bookmark47), [83](#_bookmark104), [92](#_bookmark114), [93](#_bookmark116), [168](#_bookmark215), [179](#_bookmark233), [190](#_bookmark243)

code imports [94](#_bookmark117), [179](#_bookmark233)

code init [179](#_bookmark233)

code lexer [180](#_bookmark234)

code provides [52](#_bookmark47), [84](#_bookmark106), [93](#_bookmark116)

code requires [52](#_bookmark47), [84](#_bookmark106), [93](#_bookmark116), [167](#_bookmark213)

code top [52](#_bookmark47), [93](#_bookmark116)

debug [83](#_bookmark104), [144](#_bookmark190), [190](#_bookmark243)

define [84](#_bookmark106), [86](#_bookmark108), [92](#_bookmark114), [190](#_bookmark243)

define abstract [180](#_bookmark234)

define annotations [180](#_bookmark234)

define api.location.type [87](#_bookmark110), [161](#_bookmark206), [180](#_bookmark234)

define api.namespace [87](#_bookmark110), [157](#_bookmark198)

define api.position.type [181](#_bookmark235)

define api.prefix [88](#_bookmark111)

define api.pure [81](#_bookmark101), [88](#_bookmark111)

define api.push-pull [81](#_bookmark101), [88](#_bookmark111), [177](#_bookmark230)

define api.token.constructor [89](#_bookmark112), [167](#_bookmark213)

define api.token.prefix [89](#_bookmark112)

define api.value.type [89](#_bookmark112), [181](#_bookmark235)

define api.value.type union [62](#_bookmark62)

define api.value.type variant [167](#_bookmark213)

define api.value.union.name [91](#_bookmark113)

define extends [180](#_bookmark234)

define final [180](#_bookmark234)

define implements [180](#_bookmark234)

define init\_throws [180](#_bookmark234)

define lex\_throws [180](#_bookmark234)

define location\_type [91](#_bookmark113)

define lr.default-reduction [91](#_bookmark113), [119](#_bookmark158), [121](#_bookmark161)

define lr.keep-unreachable-state [91](#_bookmark113), [122](#_bookmark163),

[123](#_bookmark165)

define lr.type [91](#_bookmark113), [118](#_bookmark156)

define package [180](#_bookmark234)

define parse.assert [92](#_bookmark114)

define parse.error [92](#_bookmark114), [102](#_bookmark133)

define parse.lac [92](#_bookmark114), [121](#_bookmark161)

define parse.trace [92](#_bookmark114), [144](#_bookmark190)

define parser\_class\_name [180](#_bookmark234)

define public [181](#_bookmark235)

define strictfp [181](#_bookmark235)

define throws [181](#_bookmark235)

defines [84](#_bookmark106), [190](#_bookmark243)

destructor [67](#_bookmark73), [77](#_bookmark92), [78](#_bookmark96), [85](#_bookmark107), [191](#_bookmark244)

dprec [23](#_bookmark12), [191](#_bookmark244)

empty [60](#_bookmark56), [191](#_bookmark244)

error-verbose [191](#_bookmark244)

expect [80](#_bookmark99), [83](#_bookmark104)

expect-rr [21](#_bookmark10), [80](#_bookmark99)

file-prefix [85](#_bookmark107), [191](#_bookmark244)

glr-parser [20](#_bookmark8), [21](#_bookmark10), [191](#_bookmark244)

initial-action [77](#_bookmark92), [191](#_bookmark244)

language [85](#_bookmark107), [191](#_bookmark244)

language "Java" [179](#_bookmark233)

left [83](#_bookmark104), [110](#_bookmark146), [191](#_bookmark244)

lex-param [101](#_bookmark130), [179](#_bookmark233), [191](#_bookmark244)

locations [85](#_bookmark107)

merge [23](#_bookmark12), [192](#_bookmark245)

name-prefix [85](#_bookmark107), [179](#_bookmark233), [192](#_bookmark245)

no-lines [85](#_bookmark107), [192](#_bookmark245)

nonassoc [83](#_bookmark104), [110](#_bookmark146), [119](#_bookmark158), [192](#_bookmark245)

output [85](#_bookmark107), [192](#_bookmark245)

param [101](#_bookmark130), [192](#_bookmark245)

parse-param [97](#_bookmark119), [179](#_bookmark233), [192](#_bookmark245)

prec [112](#_bookmark148), [192](#_bookmark245)

precedence [110](#_bookmark146), [192](#_bookmark245)

printer [79](#_bookmark97)

pure-parser [85](#_bookmark107), [192](#_bookmark245)

require [75](#_bookmark86), [85](#_bookmark107), [193](#_bookmark246)

right [83](#_bookmark104), [110](#_bookmark146), [193](#_bookmark246)

skeleton [85](#_bookmark107), [193](#_bookmark246)

start [81](#_bookmark101), [83](#_bookmark104), [193](#_bookmark246)

token [75](#_bookmark86), [83](#_bookmark104), [179](#_bookmark233), [193](#_bookmark246)

token-table [86](#_bookmark108), [193](#_bookmark246)

type [77](#_bookmark92), [83](#_bookmark104), [179](#_bookmark233), [193](#_bookmark246)

union [63](#_bookmark65), [64](#_bookmark67), [83](#_bookmark104), [193](#_bookmark246)

verbose [86](#_bookmark108)

yacc [86](#_bookmark108)

## /

/\* *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [190](#_bookmark243)

/\* ... \*/ *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [51](#_bookmark44)

// *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [190](#_bookmark243)

// ... *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [51](#_bookmark44)

## :

: *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [190](#_bookmark243)

## ;

; *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [190](#_bookmark243)

### *<*

<\*> *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [77](#_bookmark92), [79](#_bookmark97), [190](#_bookmark243)

<> *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [77](#_bookmark92), [79](#_bookmark97), [190](#_bookmark243)

## @

@$ *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [71](#_bookmark78), [105](#_bookmark138), [176](#_bookmark228), [189](#_bookmark242)

@[*name*] [71](#_bookmark78), [189](#_bookmark242)

@*n* [68](#_bookmark75), [71](#_bookmark78), [105](#_bookmark138), [176](#_bookmark228), [189](#_bookmark242)

@*name* [71](#_bookmark78), [189](#_bookmark242)

| *. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .* [59](#_bookmark54), [190](#_bookmark243)

*|*

## A

abstract syntax tree [185](#_bookmark238)

accepting state [136](#_bookmark181)

action [64](#_bookmark67)

action data types [65](#_bookmark69)

action features summary [103](#_bookmark135)

actions in mid-rule [66](#_bookmark71), [79](#_bookmark97)

actions, location [71](#_bookmark78)

actions, semantic [20](#_bookmark8)

additional C code section [57](#_bookmark51)

algorithm of parser [107](#_bookmark140)

ambiguous grammars [17](#_bookmark3), [123](#_bookmark165)

associativity [110](#_bookmark146)

AST [185](#_bookmark238)

## B

Backus-Naur form [17](#_bookmark3)

begin of location [160](#_bookmark205)

begin of Location [173](#_bookmark221)

Bison declaration summary [83](#_bookmark104)

Bison declarations [75](#_bookmark86)

Bison declarations (introduction) [56](#_bookmark49)

Bison grammar [18](#_bookmark5)

Bison invocation [149](#_bookmark194)

Bison parser [28](#_bookmark18)

Bison parser algorithm [107](#_bookmark140)

Bison symbols, table of [189](#_bookmark242)

Bison utility [28](#_bookmark18)

bison-i18n.m4 [105](#_bookmark138)

bison-po [105](#_bookmark138)

BISON\_I18N [105](#_bookmark138)

BISON\_LOCALEDIR [105](#_bookmark138)

bisonSkeleton of YYParser [175](#_bookmark226)

bisonVersion of YYParser [175](#_bookmark226)

BNF [17](#_bookmark3)

braced code [59](#_bookmark54)

build<T> on semantic\_type [158](#_bookmark201)

**C**

C code, section for additional [57](#_bookmark51)

C-language interface [97](#_bookmark119)

calc [37](#_bookmark29)

calculator, infix notation [37](#_bookmark29)

calculator, location tracking [39](#_bookmark32)

calculator, multi-function [42](#_bookmark36)

calculator, simple [31](#_bookmark21)

canonical LR [116](#_bookmark153), [118](#_bookmark156)

character token [57](#_bookmark51)

column of position [160](#_bookmark205)

columns on location [160](#_bookmark205)

columns on position [160](#_bookmark205)

comment [51](#_bookmark44)

compiling the parser [36](#_bookmark28)

conflicts [20](#_bookmark8), [21](#_bookmark10), [23](#_bookmark12), [108](#_bookmark142)

conflicts, reduce/reduce [113](#_bookmark150)

conflicts, suppressing warnings of [80](#_bookmark99)

consistent states [119](#_bookmark158)

context-dependent precedence [112](#_bookmark148)

context-free grammar [17](#_bookmark3)

controlling function [35](#_bookmark27)

core, item set [135](#_bookmark180)

## D

dangling else [108](#_bookmark142)

data type of locations [71](#_bookmark78)

data types in actions [65](#_bookmark69)

data types of semantic values [61](#_bookmark59)

debug\_level on parser [163](#_bookmark209)

debug\_stream on parser [162](#_bookmark208)

debugging [143](#_bookmark187)

declaration summary [83](#_bookmark104)

declarations [51](#_bookmark44)

declarations section [51](#_bookmark44)

declarations, Bison [75](#_bookmark86)

declarations, Bison (introduction) [56](#_bookmark49)

declaring literal string tokens [75](#_bookmark86)

declaring operator precedence [76](#_bookmark90)

declaring the start symbol [81](#_bookmark101)

declaring token type names [75](#_bookmark86)

declaring value types [62](#_bookmark62), [63](#_bookmark65), [64](#_bookmark67)

declaring value types, nonterminals [77](#_bookmark92)

default action [65](#_bookmark69)

default data type [61](#_bookmark59)

default location type [71](#_bookmark78)

default reductions [119](#_bookmark158)

default stack limit [125](#_bookmark169)

default start symbol [81](#_bookmark101)

defaulted states [119](#_bookmark158)

deferred semantic actions [25](#_bookmark13)

defining language semantics [61](#_bookmark59)

delayed syntax error detection [119](#_bookmark158), [120](#_bookmark160)

delayed yylex invocations [119](#_bookmark158)

discarded symbols [79](#_bookmark97)

discarded symbols, mid-rule actions [67](#_bookmark73)

dot [140](#_bookmark182)

## E

else, dangling [108](#_bookmark142)

empty rule [60](#_bookmark56)

end of location [160](#_bookmark205)

end of Location [173](#_bookmark221)

epilogue [57](#_bookmark51)

error [127](#_bookmark170), [191](#_bookmark244)

error on parser [163](#_bookmark209)

error recovery [127](#_bookmark170)

error recovery, mid-rule actions [67](#_bookmark73)

error recovery, simple [38](#_bookmark31)

error reporting function [102](#_bookmark133)

error reporting routine [36](#_bookmark28)

examples, simple [31](#_bookmark21)

exceptions [162](#_bookmark208)

exercises [49](#_bookmark43)

## F

file format [29](#_bookmark19)

file of position [159](#_bookmark203)

finite-state machine [113](#_bookmark150)

formal grammar [18](#_bookmark5)

format of grammar file [29](#_bookmark19)

freeing discarded symbols [77](#_bookmark92)

frequently asked questions [183](#_bookmark236)

## G

generalized LR (GLR) parsing [17](#_bookmark3), [20](#_bookmark8), [123](#_bookmark165)

generalized LR (GLR) parsing,

ambiguous grammars [23](#_bookmark12)

generalized LR (GLR) parsing,

unambiguous grammars [21](#_bookmark10)

getDebugLevel on YYParser [175](#_bookmark226)

getDebugStream on YYParser [175](#_bookmark226)

getEndPos on Lexer [176](#_bookmark228)

getErrorVerbose on YYParser [175](#_bookmark226)

getLVal on Lexer [176](#_bookmark228)

getStartPos on Lexer [176](#_bookmark228)

gettext [105](#_bookmark138)

glossary [197](#_bookmark250)

GLR parsers and inline [27](#_bookmark17)

GLR parsers and yychar [25](#_bookmark13)

GLR parsers and yyclearin [26](#_bookmark15)

GLR parsers and YYERROR [26](#_bookmark15)

GLR parsers and yylloc [25](#_bookmark13)

GLR parsers and YYLLOC\_DEFAULT [73](#_bookmark83)

GLR parsers and yylval [25](#_bookmark13)

GLR parsing [17](#_bookmark3), [20](#_bookmark8), [123](#_bookmark165)

GLR parsing, ambiguous grammars [23](#_bookmark12)

GLR parsing, unambiguous grammars [21](#_bookmark10)

GLR with LALR [118](#_bookmark156)

grammar file [29](#_bookmark19)

grammar rule syntax [59](#_bookmark54)

grammar rules section [56](#_bookmark49)

grammar, Bison [18](#_bookmark5)

grammar, context-free [17](#_bookmark3)

grouping, syntactic [17](#_bookmark3)

## H

Header guard [84](#_bookmark106)

## I

i18n [105](#_bookmark138)

IELR [116](#_bookmark153), [118](#_bookmark156)

IELR grammars [17](#_bookmark3)

infix notation calculator [37](#_bookmark29)

initialize on location [160](#_bookmark205)

initialize on position [159](#_bookmark203)

inline [27](#_bookmark17)

interface [97](#_bookmark119)

internationalization [105](#_bookmark138)

introduction [1](#_bookmark0)

invoking Bison [149](#_bookmark194)

item [135](#_bookmark180)

item set core [135](#_bookmark180)

## K

kernel, item set [135](#_bookmark180)

## L

LAC [119](#_bookmark158), [120](#_bookmark160), [121](#_bookmark161)

LALR [116](#_bookmark153), [118](#_bookmark156)

LALR grammars [17](#_bookmark3)

language semantics, defining [61](#_bookmark59)

layout of Bison grammar [29](#_bookmark19)

left recursion [60](#_bookmark56)

lexical analyzer [99](#_bookmark125)

lexical analyzer, purpose [28](#_bookmark18)

lexical analyzer, writing [34](#_bookmark26)

lexical tie-in [130](#_bookmark174)

line of position [159](#_bookmark203)

lines on location [160](#_bookmark205)

lines on position [159](#_bookmark203)

literal string token [58](#_bookmark53)

literal token [57](#_bookmark51)

location [27](#_bookmark17), [71](#_bookmark78)

location actions [71](#_bookmark78)

Location on Location [173](#_bookmark221)

location on location [160](#_bookmark205)

location tracking calculator [39](#_bookmark32)

location, textual [27](#_bookmark17), [71](#_bookmark78)

location\_type of parser [162](#_bookmark208)

lookahead correction [121](#_bookmark161)

lookahead token [107](#_bookmark140)

LR [116](#_bookmark153)

LR grammars [17](#_bookmark3)

ltcalc [39](#_bookmark32)

## M

main function in simple example [35](#_bookmark27)

make\_*token* on symbol\_type [164](#_bookmark210)

memory exhaustion [124](#_bookmark167)

memory management [124](#_bookmark167)

mfcalc [42](#_bookmark36)

mid-rule actions [66](#_bookmark71), [79](#_bookmark97)

multi-function calculator [42](#_bookmark36)

multicharacter literal [58](#_bookmark53)

mutual recursion [61](#_bookmark59)

Mysterious Conflict [118](#_bookmark156)

Mysterious Conflicts [116](#_bookmark153)

## N

named references [74](#_bookmark84)

NLS [105](#_bookmark138)

nondeterministic parsing [17](#_bookmark3), [123](#_bookmark165)

nonterminal symbol [57](#_bookmark51)

nonterminal, useless [134](#_bookmark179)

## O

operator precedence [109](#_bookmark144)

operator precedence, declaring [76](#_bookmark90)

operator!= on location [161](#_bookmark206)

operator!= on position [160](#_bookmark205)

operator+ on location [160](#_bookmark205), [161](#_bookmark206)

operator+ on position [160](#_bookmark205)

operator+= on location [160](#_bookmark205), [161](#_bookmark206)

operator+= on position [160](#_bookmark205)

operator- on location [160](#_bookmark205)

operator- on position [160](#_bookmark205)

operator-= on location [160](#_bookmark205)

operator-= on position [160](#_bookmark205)

operator<< [160](#_bookmark205), [161](#_bookmark206)

operator== on location [161](#_bookmark206)

operator== on position [160](#_bookmark205)

options for invoking Bison [149](#_bookmark194)

overflow of parser stack [124](#_bookmark167)

## P

parse error [102](#_bookmark133)

parse on parser [162](#_bookmark208)

parse on YYParser [174](#_bookmark224)

parser [28](#_bookmark18)

parser on parser [162](#_bookmark208)

parser stack [107](#_bookmark140)

parser stack overflow [124](#_bookmark167)

parser state [113](#_bookmark150)

pointed rule [135](#_bookmark180)

position on position [159](#_bookmark203)

precedence declarations [76](#_bookmark90)

precedence of operators [109](#_bookmark144)

precedence, context-dependent [112](#_bookmark148)

precedence, unary operator [112](#_bookmark148)

preventing warnings about conflicts [80](#_bookmark99)

printing semantic values [79](#_bookmark97)

Prologue [51](#_bookmark44), [92](#_bookmark114)

Prologue Alternatives [52](#_bookmark47)

pure parser [81](#_bookmark101)

push parser [81](#_bookmark101)

push\_parse on YYParser [177](#_bookmark230)

## Q

questions [183](#_bookmark236)

## R

recovering [177](#_bookmark230)

recovering on YYParser [175](#_bookmark226)

recovery from errors [127](#_bookmark170)

recursive rule [60](#_bookmark56)

reduce/reduce conflict [113](#_bookmark150)

reduce/reduce conflicts [20](#_bookmark8), [21](#_bookmark10), [23](#_bookmark12)

reduction [107](#_bookmark140)

reentrant parser [81](#_bookmark101)

requiring a version of Bison [75](#_bookmark86)

Reverse Polish Notation [31](#_bookmark21)

right recursion [60](#_bookmark56)

rpcalc [31](#_bookmark21)

rule syntax [59](#_bookmark54)

rule, empty [60](#_bookmark56)

rule, pointed [135](#_bookmark180)

rule, recursive [60](#_bookmark56)

rule, useless [134](#_bookmark179)

rules section for grammar [56](#_bookmark49)

running Bison (introduction) [36](#_bookmark28)

**S**

semantic actions [20](#_bookmark8)

Semantic predicates in GLR parsers [26](#_bookmark15)

semantic value [19](#_bookmark7)

semantic value type [61](#_bookmark59)

semantic\_type of parser [162](#_bookmark208)

set\_debug\_level on parser [163](#_bookmark209)

set\_debug\_stream on parser [162](#_bookmark208)

setDebugLevel on YYParser [175](#_bookmark226)

setDebugStream on YYParser [175](#_bookmark226)

setErrorVerbose on YYParser [175](#_bookmark226)

shift/reduce conflicts [20](#_bookmark8), [21](#_bookmark10), [108](#_bookmark142)

shifting [107](#_bookmark140)

simple examples [31](#_bookmark21)

single-character literal [57](#_bookmark51)

stack overflow [124](#_bookmark167)

stack, parser [107](#_bookmark140)

stages in using Bison [29](#_bookmark19)

start symbol [18](#_bookmark5)

start symbol, declaring [81](#_bookmark101)

state (of parser) [113](#_bookmark150)

step on location [161](#_bookmark206)

string token [58](#_bookmark53)

summary, action features [103](#_bookmark135)

summary, Bison declaration [83](#_bookmark104)

suppressing conflict warnings [80](#_bookmark99)

symbol [57](#_bookmark51)

symbol table example [44](#_bookmark40)

symbol\_type on symbol\_type [164](#_bookmark210)

symbols (abstract) [17](#_bookmark3)

symbols in Bison, table of [189](#_bookmark242)

syntactic grouping [17](#_bookmark3)

syntax error [102](#_bookmark133)

syntax of grammar rules [59](#_bookmark54)

syntax\_error of parser [162](#_bookmark208)

syntax\_error on syntax\_error [162](#_bookmark208)

## T

terminal symbol [57](#_bookmark51)

textual location [27](#_bookmark17), [71](#_bookmark78)

token [17](#_bookmark3)

token of parser [162](#_bookmark208)

token type [57](#_bookmark51)

token type names, declaring [75](#_bookmark86)

token, useless [134](#_bookmark179)

toString on Location [174](#_bookmark224)

tracing the parser [143](#_bookmark187)

## U

unary operator precedence [112](#_bookmark148)

unreachable states [122](#_bookmark163)

useless nonterminal [134](#_bookmark179)

useless rule [134](#_bookmark179)

useless token [134](#_bookmark179)

using Bison [29](#_bookmark19)

## V

value type, semantic [61](#_bookmark59)

value types, declaring [62](#_bookmark62), [63](#_bookmark65), [64](#_bookmark67)

value types, nonterminals, declaring [77](#_bookmark92)

value, semantic [19](#_bookmark7)

version requirement [75](#_bookmark86)

## W

warnings, preventing [80](#_bookmark99)

writing a lexical analyzer [34](#_bookmark26)

## X

xml [142](#_bookmark185)

## Y

YYABORT [97](#_bookmark119), [103](#_bookmark135), [177](#_bookmark230), [193](#_bookmark246)

YYACCEPT [97](#_bookmark119), [103](#_bookmark135), [177](#_bookmark230), [193](#_bookmark246)

YYBACKUP [104](#_bookmark137), [193](#_bookmark246)

yychar [25](#_bookmark13), [104](#_bookmark137), [108](#_bookmark142), [194](#_bookmark247)

yyclearin [26](#_bookmark15), [104](#_bookmark137), [128](#_bookmark171), [194](#_bookmark247)

yydebug [143](#_bookmark187), [194](#_bookmark247)

YYDEBUG [143](#_bookmark187), [194](#_bookmark247)

YYEMPTY [104](#_bookmark137)

YYENABLE\_NLS [105](#_bookmark138)

YYEOF [104](#_bookmark137)

yyerrok [104](#_bookmark137), [128](#_bookmark171), [194](#_bookmark247)

yyerror [102](#_bookmark133), [177](#_bookmark230), [194](#_bookmark247)

yyerror on Lexer [175](#_bookmark226)

yyerror on YYParser [175](#_bookmark226)

YYERROR [26](#_bookmark15), [104](#_bookmark137), [177](#_bookmark230), [194](#_bookmark247)

YYERROR\_VERBOSE [194](#_bookmark247)

YYFPRINTF [144](#_bookmark190), [194](#_bookmark247)

YYINITDEPTH [125](#_bookmark169), [194](#_bookmark247)

yylex [99](#_bookmark125), [194](#_bookmark247)

yylex on Lexer [175](#_bookmark226)

yylex on parser [163](#_bookmark209)

yylloc [25](#_bookmark13), [72](#_bookmark82), [101](#_bookmark130), [104](#_bookmark137), [108](#_bookmark142), [195](#_bookmark248)

YYLLOC\_DEFAULT [73](#_bookmark83)

YYLTYPE [101](#_bookmark130), [195](#_bookmark248)

yylval [25](#_bookmark13), [65](#_bookmark69), [100](#_bookmark128), [104](#_bookmark137), [108](#_bookmark142), [195](#_bookmark248)

YYMAXDEPTH [124](#_bookmark167), [195](#_bookmark248)

yynerrs [103](#_bookmark135), [195](#_bookmark248)

yyoutput [79](#_bookmark97)

yyparse [97](#_bookmark119), [195](#_bookmark248)

YYParser on YYParser [174](#_bookmark224)

YYPRINT [147](#_bookmark192), [195](#_bookmark248)

yypstate\_delete [99](#_bookmark125), [195](#_bookmark248)

yypstate\_new [98](#_bookmark121), [195](#_bookmark248)

yypull\_parse [98](#_bookmark121), [195](#_bookmark248)

yypush\_parse [98](#_bookmark121), [196](#_bookmark249)

YYRECOVERING [104](#_bookmark137), [128](#_bookmark171), [196](#_bookmark249)

YYSTACK\_USE\_ALLOCA [196](#_bookmark249)

YYSTYPE [196](#_bookmark249)