



A LALR(1) Parser and Lexical  
Analyzer Generator for JavaScript,  
written in JavaScript

**Version 0.30**  
**User's Manual**

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# Table of Contents

|   |    |
|---|----|
| 1.Introducing JS/CC.....                                | 3  |
| Welcome to JS/CC!.....                                  | 3  |
| The intention behind JS/CC.....                         | 4  |
| Changes on this documentation.....                      | 4  |
| Future plans.....                                       | 4  |
| Some words by the author.....                           | 5  |
| 2.A quick start example.....                            | 6  |
| Building JS/CC.....                                     | 6  |
| Installation and Start-Up.....                          | 7  |
| An example parser.....                                  | 9  |
| Compiling the example.....                              | 11 |
| 3.The Grammar Definition Language.....                  | 12 |
| General.....  | 12 |
| The Terminal Declaration Part.....                      | 12 |
| Regular Expressions.....                                | 12 |
| Ambiguous Regular Expressions.....                      | 13 |
| Associativity and Precedence.....                       | 14 |
| Whitespace.....   | 14 |
| The Grammar Definition Part.....                        | 15 |
| Accessing right-hand side items in semantic action..... | 15 |
| Value types.....  | 16 |
| Resolving conflicts.....                                | 16 |
| 4.Implementing a scripting language.....                | 18 |
| The idea.....   | 18 |
| Defining the grammar.....                               | 19 |
| Executing the script.....                               | 21 |
| The entire source.....                                  | 21 |
| 5.Debugging parsers.....                                | 29 |
| General.....  | 29 |
| Debug facilities.....                                   | 30 |
| Debugging with the Web Environment.....                 | 31 |
| License Agreements.....                                 | 32 |
| Credits.....  | 34 |

# 1.Introducing JS/CC

## Welcome to JS/CC!

JS/CC is the first available parser development system for JavaScript and ECMAScript-derivatives.

It has been developed, both, with the intention of building a productive compiler development system and with the intention of creating an easy-to-use academic environment for people interested in how parse table generation is done general in bottom-up parsing.

JS/CC is a platform-independent software that unions both: A regular expression-based lexical analyzer generator matching individual tokens from the input character stream and a LALR(1) parser generator, computing the parse tables for a given context-free grammar specification to build a stand-alone, working parser. The context-free grammar fed to JS/CC is defined in a Backus-Naur-Form-based meta language, and allows the insertion of individual semantic code to be evaluated on a rule's reduction. JS/CC itself has been entirely written in JavaScript so it can be executed in many different ways:

- as platform-independent, browser-based JavaScript embedded on a Website, which comes with a graphical parse tree generator
- as a Windows Script Host Application or a compiled JScript.NET executable
- as a Mozilla/Rhino or Mozilla/Spidermonkey interpreted application
- or as a V8 shell script

All versions can be build and run under Linux, Windows, Mac OSX and any other, \*nix-based operating system. For productive execution, it is recommended to use the command-line versions, which are capable of assembling a complete compiler from a JS/CC parser specification, which is then stored to a .js JavaScript source file.

To use JS/CC and for understanding its internals and behavior, some knowledge of context-free grammars, bottom-up parsing techniques and compiler construction theory, in general, is assumed. To get a fundamental introduction to compiler design and the different techniques and appendages on this topic, I warmly suggest to the book *Compiler Design in C*, written by Allen I. Holub<sup>1</sup>.

Maybe in future, the JS/CC user's manual itself (or I'll write a system-independent one) will provide a detailed introduction on the very huge topic of compiler construction, but for now, I limit this manual only on the usage of JS/CC itself, and its internals.

Enjoy!

---

<sup>1</sup> Allen I. Holub, **Compiler Design in C** [Prentice-Hall Software Series], ISBN 978-0131550452

## The intention behind JS/CC

JS/CC is an open source project released under the terms and conditions of the Artistic License.

When coding JS/CC started in 2007, it was just planned as a quick-and-dirty fun project of implementing a LALR(1) parser generator in JavaScript for educational purposes, but it rapidly grew up because tons of more, useful features were added through the time, that are making it a productive and usable system for parser construction and for educational issues. The most amazing thing featured by this software is, that JS/CC is capable to build a complete, working compiler for any context-free language from a grammar specification with embedded, semantic code segments within a standard web-browser like Mozilla Firefox.

Since the first public release v0.24 of JS/CC, many things have changed in this project. It received recommendations and accolades, people started to use it for production and academic issues, and some fixed bugs and ported it to other platforms.

First focused on Windows with JScript as default platform for the console version of JS/CC, the project's maintenance system changed over to Linux. Windows will still be supported, but core development is done on Linux now and in future.

## Changes on this documentation

For those who already read the last version of this manual delivered with JS/CC v0.26, you will see that much changes were made (and the documentation contains lesser pages than the previous one).

Many mistakes had been corrected, and the complete chapter 6, "Internal documentation" has been removed. The decision for removing this section is, that JS/CC's file structure has been completely changed, and much more platforms came in. Most of the internal documentation was only on describing the several source files of the package, but this information is even hold in the source files itself. So instead of revising this chapter, it is now simply removed, and the information necessary for hacking and building JS/CC remains only in the sources.

## Future plans

Development on JS/CC still moves on, and the more people using it, the more fun there is of developing it further. Both the academic and productive ideas behind JS/CC will be followed.

For future releases, a more yacc-styled behavior is planned, plus some features taken from several other, popular parser generator projects. This includes virtual productions, embedded semantics, better analysis of the parse table generation process and much more.

An alternative JS/CC front-end with a lex/yacc-like syntax would complete the whole system. It would be even possible to make JS/CC a parser generator for other target platforms than ECMAScript – but these are just ideas for now!

## Some words by the author

The kernel of JS/CC is entirely written and maintained by me, Jan Max Meyer. I'm a software developer and hobbyist programmer from Germany and was born in 1985. The art of compiler design is a study on my own, because it very much interests me and makes a lot of fun. This project is one result of this study. I never studied on computer sciences yet, but plan this somewhere in the future.

In my professional life, I work as application software developer at a local business software company. As one of my hobbies, I also run my own, tiny software company – this is J.M.K S.F. Software Technologies - from home, where I'm in writing programs and solutions around the area of software development tools, application software and some web-solutions. JS/CC is a non-profit based product of this business.

There is also another project in the area of computer-aided recognizer generation where I'm currently on, but more about this will be found out when its finished – and if I really release it.

Now, I wish you much fun and success on using JS/CC. I hope that this software will be useful in your business or just helps you on understanding how bottom-up parsing works a little more clearly.

I would deeply appreciate if you have the fun and engagement on developing JS/CC further. Share it with others, make it popular, or hack its code. That's the way it is meant to be!

So long,

Jan

PS: If you really like JS/CC and if you want to give me a smart pleasure for my efforts in developing this software, I would be very happy if you maybe take a huger or lesser donation to the WDCS – Whale and Dolphin Conservation Society – an organization that fights against the senseless killing and capturing of marine animals, like whales and dolphins, which is unfortunately the case in some countries of the world today. We must keep this world for us and our children, and stop this senseless killing of endangered animals. In my opinion, every second counts!

To support the life of whales and dolphins in our oceans, please visit <http://www.wdcs.org>.

Thank you very much.



## 2.A quick start example

### Building JS/CC

JS/CC is a platform independent software. Because of that, you have to set it up for one platform. By default, JS/CC is targeted to Mozilla/Rhino when downloading the Tarball and to Jscript, both Windows Script Host and .NET, when downloading the Windows setup.

Under Linux or your \*nix-based system, it is recommended to use GNU Make for all build-operations, under Windows, Microsoft nmake is assumed.

Currently, JS/CC can be build for the following platforms, and builds even parsers for those.

- Mozilla/Rhino
- Mozilla/Spidermonkey
- JScript (Windows Script Host)
- JScript.NET
- V8
- Web environment (HTML/JavaScript, entirely platform-independent)

The Makefile for each supported platform can be found in the src-directory, and follows the naming-convention Makefile.<platform>. To get additional help and how-to on the various platforms and how to build JS/CC there, look into the Makefile header comments.

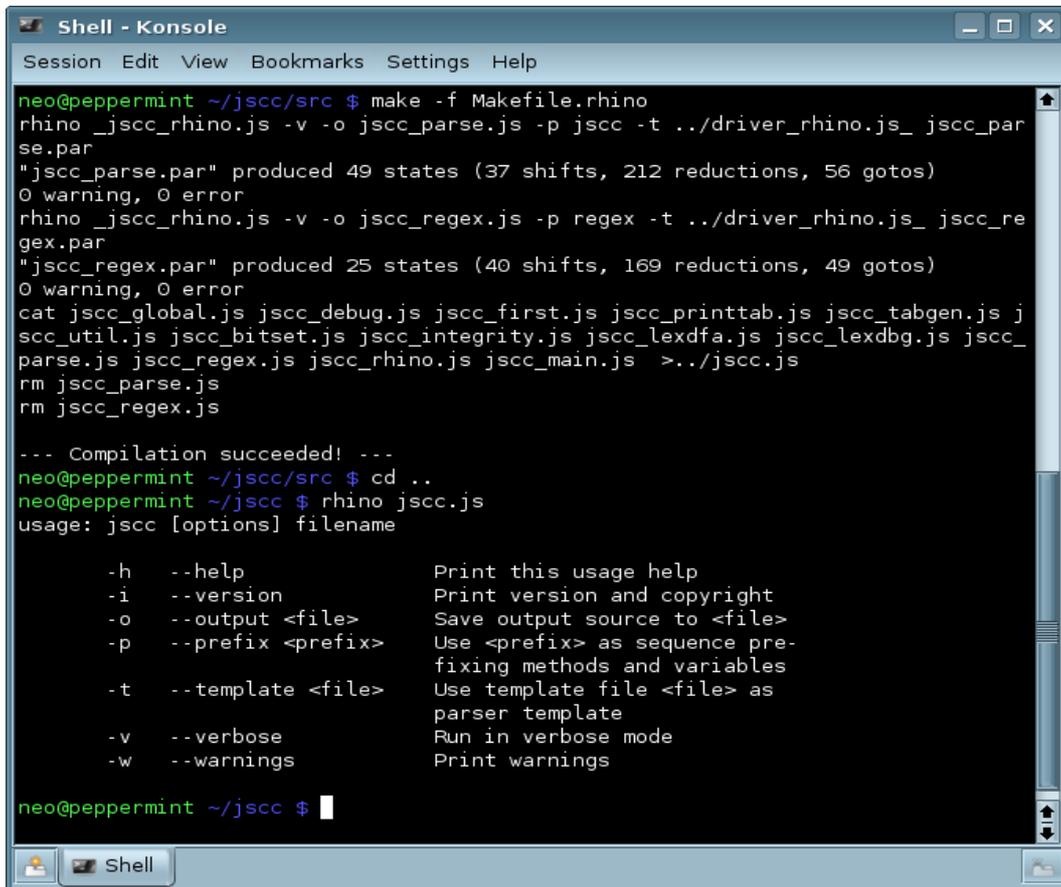
The only Makefile optimized for Windows/nmake is Makefile.jscript, all the rest uses GNU make under a \*nix environment.

## Installation and Start-Up

To install JS/CC, download the Tarball or Windows setup program. By unpacking/installing it, you get a pre-configured JS/CC environment which uses Mozilla/Rhino (Tarball), or Microsoft JScript (setup). The web-environment can be used from both editions and any operating system.

To build JS/CC for other platforms, read the build-howtos in the according Makefiles.

After you successfully built JS/CC, run it with your desired platform. Under windows, you can simply run **jsc.exe** or **cscript //Nologo jsc.js**.

A screenshot of a terminal window titled "Shell - Konsole". The terminal shows the following commands and output:

```
neo@peppermint ~/jsc/src $ make -f Makefile.rhino
rhino _jsc_rhino.js -v -o jsc_parse.js -p jsc -t ../driver_rhino.js_jsc_parse.par
"jsc_parse.par" produced 49 states (37 shifts, 212 reductions, 56 gotos)
0 warning, 0 error
rhino _jsc_rhino.js -v -o jsc_regex.js -p regex -t ../driver_rhino.js_jsc_regex.par
"jsc_regex.par" produced 25 states (40 shifts, 169 reductions, 49 gotos)
0 warning, 0 error
cat jsc_global.js jsc_debug.js jsc_first.js jsc_printtab.js jsc_tabgen.js jsc_util.js jsc_bitset.js jsc_integrity.js jsc_lexdfa.js jsc_lexdbg.js jsc_parse.js jsc_regex.js jsc_rhino.js jsc_main.js >../jsc.js
rm jsc_parse.js
rm jsc_regex.js

--- Compilation succeeded! ---
neo@peppermint ~/jsc/src $ cd ..
neo@peppermint ~/jsc $ rhino jsc.js
usage: jsc [options] filename

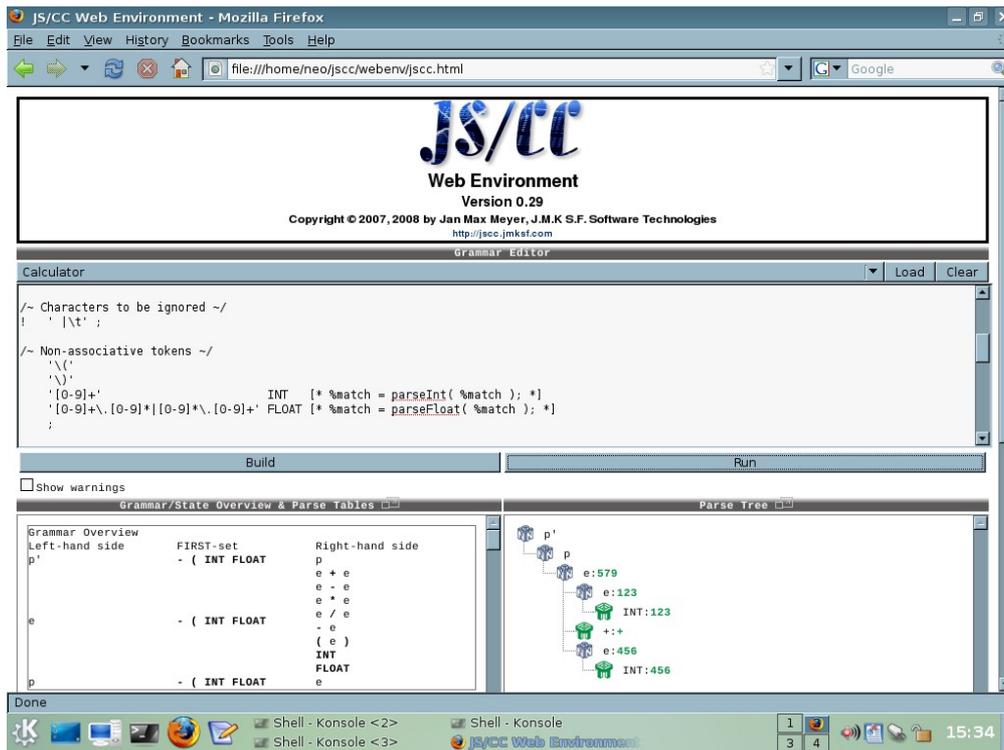
    -h  --help          Print this usage help
    -i  --version       Print version and copyright
    -o  --output <file> Save output source to <file>
    -p  --prefix <prefix> Use <prefix> as sequence prefixing methods and variables
    -t  --template <file> Use template file <file> as parser template
    -v  --verbose       Run in verbose mode
    -w  --warnings      Print warnings

neo@peppermint ~/jsc $
```

Screenshot 1: Building and invoking JS/CC from a shell

To run JS/CC with Rhino, do **rhino jsc.js**, and **smjs jsc.js** for the Spidermonkey version (or simply **./jsc.js**, when execute permission is set). **v8sh jsc.js** will run the V8 engine as platform.

To complete the list of invoking commands, run **webenv/jscc.html** with your favorite, JavaScript-enabled browser for the web environment ;).



Screenshot 2: The browser-based JS/CC web-environment

## An example parser

In parser generators like yacc, a simple parser for mathematical expressions is the most widely used example to become familiar with the syntax and usage, so we do this even here. The parser definition language itself is described below in a more detailed way.

Store the following grammar definition into a text file of your choice; For parser source files, the .PAR file extension could be used, so the file is named "calc.par" in such case.

This grammar will go with the platforms Rhino, Spidermonkey and V8. To get it to work with JavaScript, all input/output operations need to be replaced by their particular WScript calls. In Web Environment, use JavaScript's common prompt() and alert() methods.

```
/~      Expression calculator written in JS/CC      ~/
/~      Tokens to be ignored (e.g. whitespace, comments)      ~/
!      '\t'
      ;

/~      Grammar tokens      ~/
      '\+'
      '\-'
      '\*'
      '/'
      '\('
      '\)'
      '[0-9]+'          INT          [* %match = parseInt( %match ); *]
      '[0-9]+\.[0-9]*|[0-9]*\.[0-9]+'  FLOAT      [* %match = parseFloat( %match ); *]
      ;

##

/~      The non-terminal "p" is the entry symbol, because it is the first one!      ~/
program:  expr          [* print( %1 ); *]
      ;

/~      Don't confuse with the tokens: Here, we use the unescaped values because these
are not interpreted as regular expressions at this position!      ~/
expr:    expr '+' term      [* %% = %1 + %3; *]
      | expr '-' term      [* %% = %1 - %3; *]
      | term                ~/ Default semantic action fits here! ~/
      ;

term:    term '*' factor    [* %% = %1 * %3; *]
      | term '/' factor    [* %% = %1 / %3; *]
      | factor              ~/ Default semantic action fits here! ~/
      ;

factor:  '(' expr ')'      [* %% = %2; *]
      | INT                ~/ Default semantic action fits here! ~/
      | FLOAT              ~/ Default semantic action fits here! ~/
      ;

/~      This is the parser entry point; Because this entry point could be very individual,
```

```

        the compiler programmer has to decide which way he wants to read the source, parse
        it and report the errors, if there are any.                                     ~/  

/*  

var error_offsets = new Array();  

var error_lookaheads = new Array();  

var error_count = 0;  

//We're getting the expression via command line parameter  

var str = new String( arguments[0] );  

/*  

    The "##PREFIX##" is a wild card, where an optional, unique name will be inserted by  

    JS/CC when the parser is constructed. This enables the possibility to use multiple  

    different parsers in one project or script.  

*/  

*/  

if( ( error_count = __##PREFIX##parse( str,  

    error_offsets, error_lookaheads ) ) > 0 )  

{  

    for( i = 0; i < error_count; i++ )  

        print( "Parse error near \""  

            + str.substr( error_offsets[i] ) +  

            "\", expecting \"" +  

            error_lookaheads[i].join() +  

            "\"" );  

}  

*/

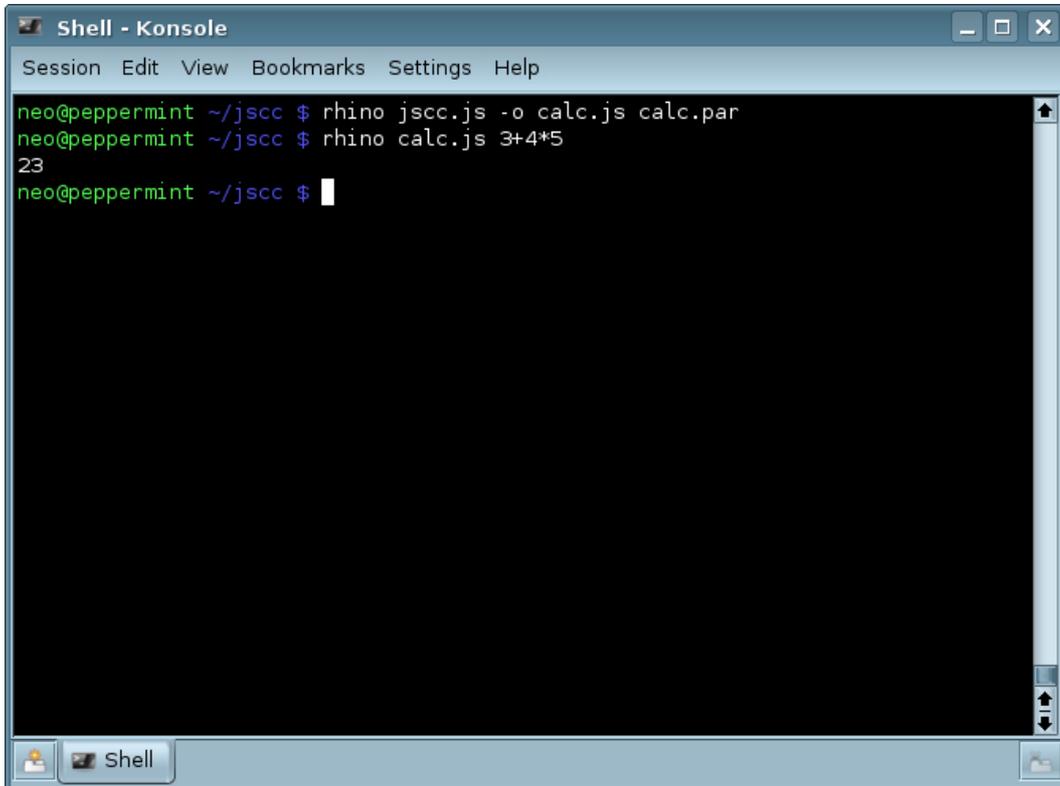
```

## Compiling the example

To compile a working parser from the example described above, run JS/CC like as follows

```
rhino jsc.js -o calc.js calc.par
```

That's all! The result, calc.js, can now simply be executed using your desired platform.



```
Shell - Konsole
Session Edit View Bookmarks Settings Help
neo@peppermint ~/jsc $ rhino jsc.js -o calc.js calc.par
neo@peppermint ~/jsc $ rhino calc.js 3+4*5
23
neo@peppermint ~/jsc $
```

*Screenshot 3: Compiling and executing the calculator example*

As all \*nix-like programs, JS/CC does output nothing when its invoked and successfully build the parser. The verbose-option prints out some statistics, e. g. how many states and actions had been created in the resulting parse table.

# 3.The Grammar Definition Language

## General

As you can get from the expression calculator example above, the grammar definition language of JS/CC consists of two parts: The token definition part, and the grammar part, which defines the language's grammar using a Backus-Naur-Form-styled meta language. The two parts are separated by a **##** symbol, which could be seen as a "separating line" between both parts.

[Some things in the current version of the JS/CC grammar definition language are a little bit nasty and need to be reworked in future – like this **##** separator...]

## The Terminal Declaration Part

Tokens, or terminal symbols, are defined in the upper part of each grammar definition file. These terminals are defined using a regular expression meta language, but it's also possible to give each terminal symbol an individual name and a individual code segment to be executed when this token is recognized by the generated lexical analyzer (e. g. to cut the leading and trailing quotation marks if a string is recognized from the token's attribute).

The general syntax to define tokens is

```
regular-expression label code
      .
      .
      .
;
```

where *label* and *code* is optional.

The regular expression is specified in the ways described below, using a single- or double-quoted string.

A token's label is defined as a single word identifier, e. g. "FLOAT" or "INTEGER\_NUMBER". Not allowed are separated words. If no label is specified, JS/CC uses the regular-expression definition itself as label, but without taking escape-characters, so the regular expression '\+' will result in the label '+', as in the above example. If '+' itself is specified as regular expression, a parse error will occur because the plus-character is the symbol for a positive closure in regular expressions.

A semantic code action is defined by enclosing the desired JavaScript code segment with a [\* and \*] symbol. If more than one code segment is specified in a row, all segments are summarized to one segment to be attached to the terminal symbol. To simply access things like the matched pattern, the offset where the pattern starts or the source string in this individual code segments, the wild cards **%match**, **%offset** and **%source** should be used. These wild cards are later substituted by the particular variable names in the resulting lexical analyzer.

Because JS/CC does also allow to pass precedence and associativity information to tokens or token groups, each block of token definitions is closed by a semicolon (;). Because of that, the semicolon is set behind the last token definition also in the above example, even if we don't use any precedence information here.

## Regular Expressions

Because it was impossible to build a properly working lexical analyzer using JavaScript's build-in RegExp-object, JS/CC features its own implementation of regular expression processing. This is also the reason that not all the features of the JavaScript RegExp-object are provided, like back-references and predefined character classes.

The symbols and operators to be used within JS/CC's own regular expression language are summarized in the following table.

They form a minimal implementation of a regular expression engine.

| <i>Language Element</i>   | <i>Description</i>   |
|---------------------------|--|
| <b><i>character</i></b>   | One character specifies exactly that character; If a regular-expression operator like + or * should be used, it must be escaped via \.   |
| <b><i>\ascii-code</i></b> | One character, defined via ASCII-code, e.g. "\220" matches the Ü-umlaut of the extended ASCII-table.   |
| <b><i>\character</i></b>  | Escaped character. Must be used when a character of the meta-language itself should be matched, e.g. "\\".   |
| .                         | Any character (character class matching all available characters).   |
| [...]                     | Character-class; If a beginning circumflex (^) is given, the character-class is negated. Character ranges can be specified using a dash. For example "[A-Za-z]" specifies all capital and lower-case alphabet letters. |
| (...)                     | Sub-expression.  |
|                           | Or-operator; Allows to specify different expressions at one level.   |
| *                         | Kleene-closure operator (none or many), to be specified behind a character, character-class or sub-expression.   |
| +                         | Positive-closure operator (one or many), to be specified behind a character, character-class or sub-expression.  |
| ?                         | Optional-closure operator (one or none), to be specified behind a character, character-class or sub-expression.  |

*Table 1: JS/CC own regular expression meta language*

Even to allow case-insensitive keywords within grammar definitions, a terminal symbol definition can be specified using single-quoted ('...') and double-quoted ("...") strings. A single-quoted string means that a terminal symbol is matched case-sensitive, a double-quoted one matches a terminal in any case order. For example, the terminal symbol definition "PRINT" will match for *Print*, *print*, *PrINT* and *PRINT*, while the definition 'PRINT' will only match for *PRINT* itself.

From these regular expression definitions, JS/CC constructs a deterministic finite automation which acts as lexer in the resulting parser.

### **Ambiguous Regular Expressions**

If there are ambiguous regular expressions (where several expressions match the same string) within the terminal definition part, the expressions defined upper in the terminal definition part will take higher match precedence than the lower defined terminals. It is recommended to define tokens with a higher specialization level as the first, and tokens with a lower level as the last in

your token definition part.

### **Associativity and Precedence**

Tokens can be grouped by precedence levels and associativity. This feature allows to write faster and even smaller grammars, by resolving grammar conflicts by weighting terminal symbols.

A group without a group specifier will set no associativity and a precedence level of zero to all terminal symbols in this group (as in the first example).

Else, if a group begins with the symbol < for left-associativity, > for right-associativity and ^ for non-associativity, all terminal symbols within this group are set to the according associativity and precedence level. The precedence level is incremented each time a new group of these three types is opened, so groups that are defined at the bottom of the token definition part take the highest precedence.

The precedence information as associativity is used to resolve conflicts in ambiguous grammars by modifying the parse table's natural content; How this works in practice and what ways and possibilities there are is described below in the section dealing with grammar conflicts and their handling.

### **Whitespace**

A special type of terminal symbol is introduced by the exclamation-mark (!) symbol: The whitespace symbols!

In this definition, there is only one regular expression possible; A label or code part is prohibited. As whitespace-tokens, terminals that should always be ignored can be specified, e. g. blanks, tabs or comments.

## The Grammar Definition Part

The lower – and most important - part of a JS/CC parser definition is the grammar definition part. In this part, below the **##** symbol, the definition of the context-free grammar to be parsed by the generated parser is described. This is done by using a Backus-Naur-Form variant meta language, by defining non-terminals and their productions.

The general syntax for a non-terminal and its productions is

```
non-terminal      : production1 semantic-code  
                  | production2 semantic-code  
                  .  
                  .  
                  .  
                  | productionn semantic-code  
                  ;
```

The *non-terminal* defines a single-word identifier and acts as the left-hand side for the related productions attached to this symbol.

The *production* defines a sequence of zero or multiple terminals and non-terminals, defining the different syntax rules. To specify terminal symbols, it is possible to call them via their (unescaped) regular expression (as described above!) via a string-value or by their label, which must not (but can) be specified as a string value. In the example of the quick start part, both methods are used: FLOAT is called by its label, the token '+', for better readability, is called by its generated name which came from the regular expression.

The semantic-code part behind the productions is optional, and defines an individual semantic code which is executed right before the according production is reduced to its left hand side. Same as in the token definition part, semantic code is enclosed by [**\*** and **\***] and will be concatenated to one code segment which is associated with the according productions when multiple semantic code segments are specified in a row. Read more about this in the section below.

Note that in the above syntax scheme the number of productions is completely variable. At least, one right-hand side must be given to an according left-hand side, although this can be an epsilon production.

Each production is separated by a vertical "pipe" bar (|) from the others, and a non-terminal definition must always be closed by a semicolon. Else, JS/CC can not distinguish if the next symbol belongs to the right-hand side it currently parses or if it reads a new non-terminal definition.

Non-terminal symbols can be called on a right-hand side before they are defined, so the way the rules are defined is arbitrary. Integrative checks on the grammar are done by JS/CC before the parse tables will be constructed.

### Accessing right-hand side items in semantic action

Within each semantic action attached to a production, as described above, the values of the right-hand side symbols can be accessed via wild cards, which are replaced by the particular variables and offsets later in the resulting parser.

The %n wild cards are used to address every individual token starting from the left of the right-hand side.

The %% wild card relates to the value of the left-hand side which is pushed to the parser's value stack right after the right-hand side symbols are popped.

So by passing a value to the %% wild card causes the inheritance of values from the current right-hand side to another call of the according non-terminal on a right-hand side within the parse tree. The values on the current right-hand side will be discarded when the reduction process occurs, and the value attached to %% is pushed instead, so it can be used elsewhere.

As example, in the given production

```
expr:          expr '+' term          [* %% = %1 + %3; *]
```

of the above expression calculator, the return values of the *expr* and the *term* on the right-hand side, which are addressed via %1 and %3 (%2 addresses the value of the '+'-terminal!) are added together, and the result is stored to the left hand-side (the *expr* on the far left in this case). Thus, you have full control over all individual tokens within each production.

If no individual semantic action is given to a right-hand side, the default action

```
%% = %1;
```

is used.

Semantic action between the symbols of a right-hand side is not allowed, only behind them.

## Value types

Because JS/CC was designed for the use with JavaScript, or any other typeless scripting language, it is not necessary to define – as in yacc – a special union structure to hold the values on the value stack. Both build-in primary types like String or Number objects as well as user-defined objects [each function in JavaScript is internally represented by an object] can be pushed to and popped off the value stack.

So don't confuse with the values; You have to know which objects you push on the stack!

## Resolving conflicts

To automatically resolve shift-reduce or reduce-reduce conflicts at parse table generation, JS/CC features, by default, two mechanisms.

When a shift-reduce conflict occurs, JS/CC constructs the parse tables in favor of the shift, so the parse tree will grow right derivative.

When a reduce-reduce conflict occurs, JS/CC resolves the problem by reducing the production which was defined first, so productions which where defined above in the grammar will be reduced in favor when this conflict comes up.

As shortly described in the chapter about terminal symbol definition, JS/CC features the possibility of manipulating the natural parse table generated by the LALR(1) table construction algorithm by weighting terminal symbols with a precedence level and an associativity. This information is used within shift-reduce conflicts to better decide if a shift or a reduce operation should be inserted. If a shift-reduce conflict comes up, the precedence level and associativity information is compared with the according production's precedence level, because every production will, by default, get the same precedence level as its rightmost terminal symbol.

To explain this behavior, let's look at the following example. It defines a calculator same as the first example, but with lesser effort in writing the grammar; Here, we have only two non-terminal symbols instead of four, but we implement the same operator precedence behavior as in the original one.

```
/~ Tokens to be ignored (e. g. whitespace, comments) ~/
!      ' |\t';

/~      Left-associative tokens, lowest precedence      ~/
<      '\+'
      '\-';

/~      Left-associative tokens, highest precedence     ~/
<      '\*'
```

```

    '/';

/~      Tokens with no associativity      ~/
    '\('
    '\)'
    '[0-9]+'          INT          [* %match = parseInt( %match ); *]
    '[0-9]+\.[0-9]*|[0-9]*\.[0-9]+'    FLOAT      [* %match = parseFloat( %match ); *]
    ;

##

program:  expr          [* print( %1 ); *]
        ;

expr:     expr '+' expr    [* %% = %1 + %3; *]
        | expr '-' expr    [* %% = %1 - %3; *]
        | expr '*' expr    [* %% = %1 * %3; *]
        | expr '/' expr    [* %% = %1 / %3; *]
        | '(' expr ')'     [* %% = %2; *]
        | INT
        | FLOAT
        ;

```

Sometimes, it will also be necessary to give a production another precedence level than the one of the rightmost terminal. For example, if we want to add an unary minus operator to the grammar above, the production adopts the precedence level of the minus-symbol by default. But this minus-operator was configured for its use in a binary subtraction, not in an unary subtraction. By simply adding a new rule for unary minus to the grammar, most simple expressions will return the right result (e. g. "-2+3"), but in expressions like "4/-4\*5", the result will be wrong, because, through our precedence rules for multiplication, the generated parser parses "4/(-(4\*5))" instead of "(4/(-4))\*5".

To resolve this problem, we need to attach a higher precedence level to the production for unary minus. For this special case, JS/CC features the **&**-directive. The **&**-directive must be specified behind the rule's definition and in front of the semantic code action (if there is any). Behind the **&**-directive, a terminal symbol (both as string or its label) is specified, which precedence level is taken by the production instead of its default value.

So by changing the grammar to

```

expr:     expr '+' expr    [* %% = %1 + %3; *]
        | expr '-' expr    [* %% = %1 - %3; *]
        | expr '*' expr    [* %% = %1 * %3; *]
        | expr '/' expr    [* %% = %1 / %3; *]
        | '(' expr ')'     [* %% = %2; *]
        | '-' expr         &'*'    [* %% = %2 * -1; *]
        | INT
        | FLOAT
        ;

```

we get the right parse tree and result, because our rule with the unary minus has a higher precedence now and reduces instead of shifting in the desired cases.

# 4. Implementing a scripting language

## The idea

As an example for a real mini-compiler, we will now implement a simple, interpreted programming language, called XPL (eXample Programming Language) using JS/CC. XPL is a C-styled script language interpreter, providing simple user input/output operations, loops and conditional execution as well as variables. As variable type, only numbers are supported (integer and floating point, all use the same, internal JavaScript type "Number"). The Definition of user-defined functions is not possible in this scripting language, but it would be a thing of simplicity to add this feature.

For text output, XPL provides a special say-command which allows to output constant texts. To get familiar with XPL's syntax, look at the following example scripts.

### *hello.xpl:*

```
//This is a simple Hello World script, written in XPL.  
say 'Hello World';
```

### *99-bottles-of-beer.xpl:*

```
//The wonderful "99 bottles of beer"-program  
bottles = 99;  
do  
{  
    //The output will not be the prettiest, but that is limited  
    //by the implementation (you can change it if you want ;))  
    write bottles;  
  
    if bottles == 1 say 'bottle of beer on the wall,';  
    else say 'bottles of beer on the wall,';  
  
    write bottles;  
    if bottles == 1  
        say 'bottle of beer';  
    else  
        say 'bottles of beer';  
  
    say 'Take one down, pass it around,';  
    bottles = bottles - 1;  
  
    write bottles;  
    if bottles == 0 say 'no more bottles of beer on the wall';  
    else if bottles == 1 say 'bottle of beer on the wall';  
    else say 'bottles of beer on the wall';  
  
    say '';    //Empty line  
}  
while bottles > 0;  
  
say 'That''s it!';
```

### countdown.xpl:

```
//A rocketry launch countdown ;)
say '--- The final countdown program ---';

do
{
    say 'Enter your starting number (it must be greater or equal 10!):';
    read count;

    if count < 10 say 'The number is lower 10!';
}
while count < 10;

say 'Starting sequence...';
while count >= 0 do
{
    write count;

    //Ignition at 3 loops before lift-off...
    if count == 3 say 'Ignition...';
    else if count == 0 say '...and lift-off!';
    count = count - 1;
}
```

## Defining the grammar

The grammar definition for the XPL-grammar consists of less than 80 lines of grammar definition.

```
!      ' |\r|\n|\t|//[^\n]*\n'

      "IF"
      "ELSE"
      "WHILE"
      "DO"
      "SAY"
      "WRITE"
      "READ"
      '{ '
      '}'
      ';'
      '\ ('
      '\)'
      '='
      '[A-Za-z_][A-Za-z0-9_]*'          Identifier
      '\'([\^']|\\')*\''             String
      '[0-9]+'                        Integer
      '[0-9]+\.[0-9]*|[0-9]*\.[0-9]+'  Float
      ;

>      '=='
      '!='
      '<='
```

```

    '>='
    '>'
    '<'
    ;

<    '\+'
    '\-'
    ;

<    '/'
    '\*'
    ;

##

Program:          Program Stmt
                  |
                  ;

Stmt_List:       Stmt_List Stmt
                  |
                  ;

Stmt:            IF Expression Stmt
                  | IF Expression Stmt ELSE Stmt
                  | WHILE Expression DO Stmt
                  | DO Stmt WHILE Expression ';'
                  | SAY String ';'
                  | WRITE Expression ';'
                  | READ Identifier ';'
                  | Identifier '=' Expression ';'
                  | '{' Stmt_List '}'
                  | ';'
                  ;

Expression:      Expression '==' Expression
                  | Expression '<' Expression
                  | Expression '>' Expression
                  | Expression '<=' Expression
                  | Expression '>=' Expression
                  | Expression '!=' Expression
                  | Expression '-' Expression
                  | Expression '+' Expression
                  | Expression '*' Expression
                  | Expression '/' Expression
                  | '-' Expression                &'*'
                  | '(' Expression ')'
                  | Integer
                  | Float
                  | Identifier
                  ;

```

## Executing the script

It is impossible to interpret an XPL script directly like in the first expression calculator example. It probably works also here, but only in expressions. Statements like **while...do** or **if...else** are not directly interpretable, because they have a body and a conditional part. Because of that, we need to compile the program internally into a structure for a virtual machine. This virtual machine uses an assembly like command language, working with opcodes and operands, and running recursively on a tree-structured compilation.

The parser has the purpose to build-up a cascading structure of nodes, which form the program that can be executed. This method avoids the use of dealing with jumps to addresses, but cannot be used to be written to a file.

Note that this compiler will not compile into an assembly code file. The “assembly” program is constructed directly into the memory as an internal structure. The virtual machine executing this structure will at least exist of one function, which calls itself recursively based on the operation it executes.

## The entire source

This is the entire, augmented program code for the XPL compiler and interpreter, based on the grammar definition from above.

A script is executed from a file, which must be attached to the script at startup.

Note that this code is for JScript to be executed using `cscript`. To port it to another platform, I/O methods must be replaced or rewritten.

```
/~

XPL - eXample Programming Language v0.3
Written 2007 by J.M.K S.F. Software Technologies, Jan Max Meyer

The complete source of this program is in the Public Domain.

This example demonstrates the implementation of XPL, a complete,
interpreted scripting language, written in JS/CC.

XPL provides simple input/output operations and can only handle
numeric values.

Watch out for the *.xpl-files within the example directory, which
contain example scripts to be executed using XPL.

~/

[*

//Structs
function NODE()
{
    var type;
    var value;
    var children;
}

//Defines
```

```

var NODE_OP          = 0;
var NODE_VAR        = 1;
var NODE_CONST      = 2;

var OP_NONE         = -1;
var OP_ASSIGN       = 0;
var OP_IF           = 1;
var OP_IF_ELSE     = 2;
var OP_WHILE_DO     = 3;
var OP_DO_WHILE    = 4;
var OP_WRITE        = 5;
var OP_READ         = 6;
var OP_SAY          = 7;

var OP_EQU          = 10;
var OP_NEQ          = 11;
var OP_GRT          = 12;
var OP_LOT          = 13;
var OP_GRE          = 14;
var OP_LOE          = 15;
var OP_ADD          = 16;
var OP_SUB          = 17;
var OP_DIV          = 18;
var OP_MUL          = 19;
var OP_NEG          = 20;

//Management functions
function createNode( type, value, childs )
{
    var n = new NODE();
    n.type = type;
    n.value = value;
    n.children = new Array();

    for( var i = 2; i < arguments.length; i++ )
        n.children.push( arguments[i] );

    return n;
}

//Array to store variable names and values to
var v_names = new Array();
var v_values = new Array();

//Function to store a variable's content to a variables name. If the name does
//not exist already, the variable is automatically created.
function letvar( vname, value )
{
    var i;
    for( i = 0; i < v_names.length; i++ )
        if( v_names[i].toString() == vname.toString() )

```

```

        break;

    if( i == v_names.length )
    {
        v_names.push( vname );
        v_values.push( 0 );
    }

    v_values[i] = value;
}

//Function to get a variable's content over its name
function getvar( vname )
{
    var i;
    for( i = 0; i < v_names.length; i++ )
        if( v_names[i].toString() == vname.toString() )
            return v_values[i];

    return 0;
}

//This is the interpreting function, working on base of the compiled program structure.
function execute( node )
{
    var ret = 0;

    if( !node )
        return 0;

    switch( node.type )
    {
        case NODE_OP:
            switch( node.value )
            {
                case OP_NONE:
                    /* OP_NONE can have childs (a block!) */
                    if( node.children[0] )
                        execute( node.children[0] );
                    if( node.children[1] )
                        ret = execute(
                            node.children[1] );
                    break;
                case OP_ASSIGN:
                    letvar( node.children[0], execute(
                        node.children[1] ) );
                    break;
                case OP_IF:
                    if( execute( node.children[0] ) )
                        execute( node.children[1] );
                    break;
            }
    }
}

```

```

case OP_IF_ELSE:
    if( execute( node.children[0] ) )
        execute( node.children[1] );
    else
        execute( node.children[2] );
    break;
case OP_WHILE_DO:
    while( execute( node.children[0] ) )
        execute( node.children[1] );
    break;
case OP_DO_WHILE:
    do
        execute( node.children[0] )
    while( execute( node.children[1] ) );
    break;
case OP_WRITE:
    WScript.Echo( execute( node.children[0] )
        );
    break;
case OP_READ:
    letvar( node.children[0].toString(),
        WScript.StdIn.ReadLine() );
    break;
case OP_SAY:
    WScript.Echo( node.children[0] );
    break;
case OP_EQU:
    ret = execute( node.children[0] ) ==
        execute( node.children[1] );
    break;
case OP_NEQ:
    ret = execute( node.children[0] ) !=
        execute( node.children[1] );
    break;
case OP_GRT:
    ret = execute( node.children[0] ) >
        execute( node.children[1] );
    break;
case OP_LOT:
    ret = execute( node.children[0] ) <
        execute( node.children[1] );
    break;
case OP_GRE:
    ret = execute( node.children[0] ) >=
        execute( node.children[1] );
    break;
case OP_LOE:
    ret = execute( node.children[0] ) <=
        execute( node.children[1] );
    break;
case OP_ADD:

```

```

        ret = execute( node.children[0] ) +
                execute( node.children[1] );
        break;
    case OP_SUB:
        ret = execute( node.children[0] ) -
                execute( node.children[1] );
        break;
    case OP_DIV:
        ret = execute( node.children[0] ) /
                execute( node.children[1] );
        break;
    case OP_MUL:
        ret = execute( node.children[0] ) *
                execute( node.children[1] );
        break;
    case OP_NEG:
        ret = execute( node.children[0] ) * -1;
        break;
    }
    break;

    case NODE_VAR:
        ret = Number( getvar( node.value ) );
        break;

    case NODE_CONST:
        ret = Number( node.value );
        break;
    }
    return ret;
}

*]

/~ Defining whitespaces and comments ~/
!      ' |\r|\n|\t|//[^\n]*\n'

/~ Keywords (case-insensitive!) and program structure operators ~/
"IF"
"ELSE"
"WHILE"
"DO"
"SAY"
"WRITE"
"READ"
'{'
'}'
';'
'\('
'\)'
'='

```

```

'[A-Za-z_][A-Za-z0-9_]*'      Identifier
'\'([\^\'|\\\'')*\''      String      [* %match = %match.substr( 1,
                                %match.length - 2 );
                                %match = %match.replace( /'/g,
                                "\'" );
                                *]

'[0-9]+'                      Integer
'[0-9]+\.[0-9]*|[0-9]*\.[0-9]+'  Float
;

/~ Operators to be used in expressions ~/
>      '=='
      '!='
      '<='
      '>='
      '>'
      '<'
      ;

<      '\+'
      '\-'
      ;

<      '/'
      '\*'
      ;

##

Program:      Program Stmt      [* execute( %2 ); *]
      |
      ;

Stmt_List:    Stmt_List Stmt    [* %% = createNode( NODE_OP,
                                OP_NONE, %1, %2 ); *]
      |
      ;

Stmt:         IF Expression Stmt  [* %% = createNode( NODE_OP,
                                OP_IF, %2, %3 ); *]
      | IF Expression Stmt ELSE Stmt  [* %% = createNode( NODE_OP,
                                OP_IF_ELSE, %2, %3, %5 ); *]
      | WHILE Expression DO Stmt    [* %% = createNode( NODE_OP,
                                OP_WHILE_DO, %2, %4 ); *]
      | DO Stmt WHILE Expression ';'  [* %% = createNode( NODE_OP, OP_DO_WHILE,
                                %2, %4 ); *]
      | SAY String ';'              [* %% = createNode( NODE_OP, OP_SAY,
                                %2 ); *]
      | WRITE Expression ';'        [* %% = createNode( NODE_OP, OP_WRITE,
                                %2 ); *]
      | READ Identifier ';'         [* %% = createNode( NODE_OP, OP_READ,

```

```

        %2 ); *]
| Identifier '=' Expression ';'      [* %% = createNode( NODE_OP, OP_ASSIGN,
                                     %1, %3 ); *]
| '{' Stmt_List '}'                  [* %% = %2; *]
| ';'                                  [* %% = createNode( NODE_OP, OP_NONE );
*]
;

Expression:
Expression '==' Expression           [* %% = createNode( NODE_OP, OP_EQU,
                                     %1, %3 ); *]
| Expression '<' Expression           [* %% = createNode( NODE_OP, OP_LOT,
                                     %1, %3 ); *]
| Expression '>' Expression           [* %% = createNode( NODE_OP, OP_GRT,
                                     %1, %3 ); *]
| Expression '<=' Expression          [* %% = createNode( NODE_OP, OP_LOE,
                                     %1, %3 ); *]
| Expression '>=' Expression          [* %% = createNode( NODE_OP, OP_GRE,
                                     %1, %3 ); *]
| Expression '!=' Expression         [* %% = createNode( NODE_OP, OP_NEQ,
                                     %1, %3 ); *]
| Expression '-' Expression          [* %% = createNode( NODE_OP, OP_SUB,
                                     %1, %3 ); *]
| Expression '+' Expression          [* %% = createNode( NODE_OP, OP_ADD,
                                     %1, %3 ); *]
| Expression '*' Expression          [* %% = createNode( NODE_OP, OP_MUL,
                                     %1, %3 ); *]
| Expression '/' Expression          [* %% = createNode( NODE_OP, OP_DIV,
                                     %1, %3 ); *]
| '-' Expression      &'*'          [* %% = createNode( NODE_OP, OP_NEG,
                                     %2 ); *]
| '(' Expression ')'                 [* %% = %2; *]
| Integer                            [* %% = createNode( NODE_CONST, %1 ); *]
| Float                              [* %% = createNode( NODE_CONST, %1 ); *]
| Identifier                          [* %% = createNode( NODE_VAR, %1 ); *]
;

[*
//Utility function: Open and read a file
function open_file( file )
{
    var fs = new ActiveXObject( 'Scripting.FileSystemObject' );
    var src = new String();

    if( fs && fs.fileExists( file ) )
    {
        var f = fs.OpenTextFile( file, 1 );
        if( f )
        {

```

```

        src = f.ReadAll();
        f.Close();
    }
}

return src;
}

//Main
if( WScript.Arguments.length > 0 )
{
    var str          = open_file( WScript.Arguments(0) );
    var error_cnt    = 0;
    var error_off    = new Array();
    var error_la     = new Array();

    if( ( error_cnt = __##PREFIX##parse( str, error_off, error_la ) ) > 0 )
    {
        for( i = 0; i < error_cnt; i++ )
            WScript.Echo( "Parse error near \""
                + str.substr( error_off[i], 10 ) +
                ( ( str.length > error_off[i] + 10 ) ? "...\" : \"\" ) +
                "\", expecting \"" + error_la[i].join() + "\"" );
    }
}
else
    WScript.Echo( 'usage: xpl.js <filename>' );
*]

```

# 5. Debugging parsers

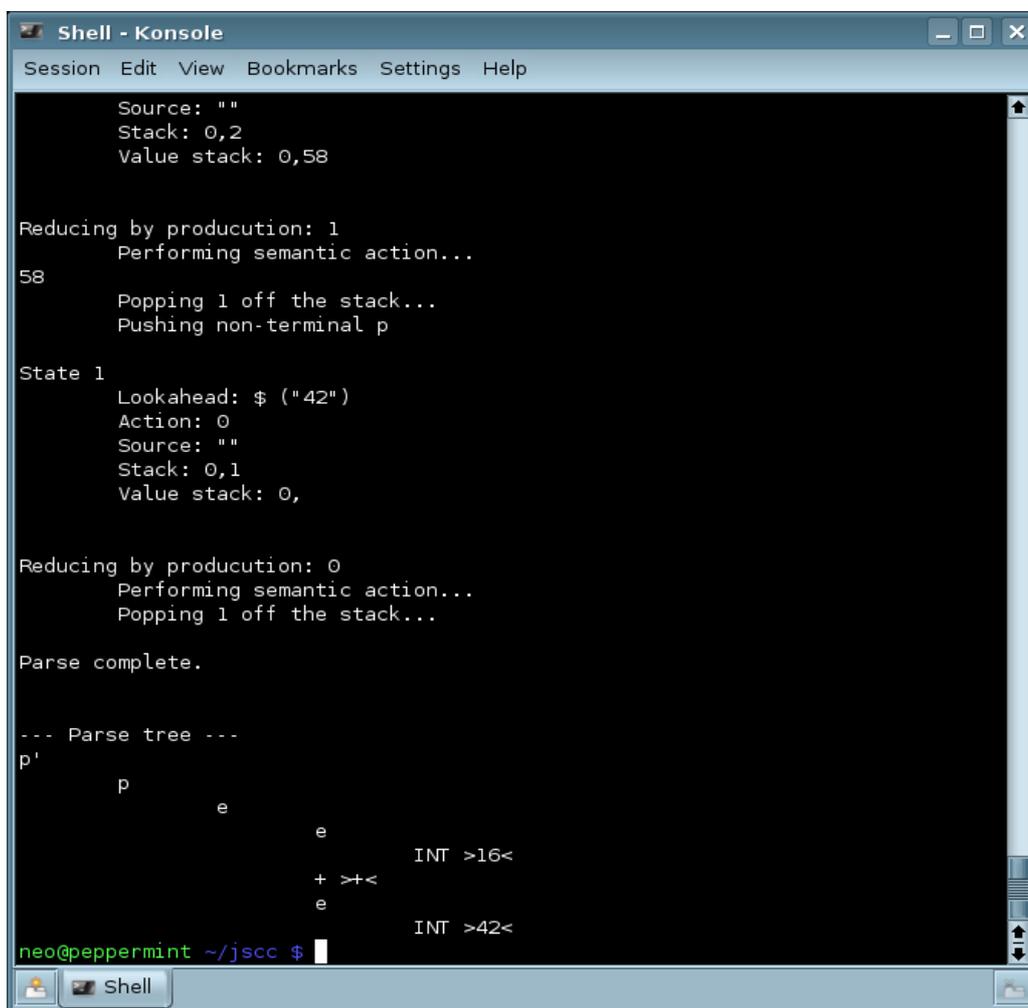
## General

When JS/CC compiles a grammar, the parse tables are inserted into a so called driver template which is then executing the state machine based on the content of the parse tables.

These parser drivers offer several methods to debug grammars, depending on their platform.

JS/CC comes with several parser driver templates for the different platforms it supports. They are specified in the files `driver_<platform>.js_`. To build an executable parser, JS/CC uses one of these templates and copies the generated (dynamically generated) parse tables and arbitrary information into placeholders within the templates. The result of this process is the executable parser script.

The grammar debugging features of the respective parse table driver are enabled by setting some global variables to true.



```
Shell - Konsole
Session Edit View Bookmarks Settings Help

Source: ""
Stack: 0,2
Value stack: 0,58

Reducing by production: 1
  Performing semantic action...
58
  Popping 1 off the stack...
  Pushing non-terminal p

State 1
  Lookahead: $ ("42")
  Action: 0
  Source: ""
  Stack: 0,1
  Value stack: 0,

Reducing by production: 0
  Performing semantic action...
  Popping 1 off the stack...

Parse complete.

--- Parse tree ---
p'
  p
    e
      e
        INT >16<
      + >+<
    e
      INT >42<

neo@peppermint ~/jsc $
```

Screenshot 4: Console-based parser debugging - Parse trace and parse tree

## Debug facilities

To enable the debugging facilities in console-based parsers, you can set the following variables, depending on your requests.

- Trace (set **##PREFIX##\_dbg\_withtrace** to true)  
The parse trace provides information about each parser state which is entered with which input tokens, parse stack and value stack. This feature is very useful to understand the parse process and to detect possible value access errors.
- Step-by-step (set **##PREFIX##\_dbg\_withstepbystep** to true)  
This can only be used in conjunction with the parse trace, and waits that the user presses enter to continue to the next state. Has no effect when trace is switched off.
- Parse tree generation (set **##PREFIX##\_dbg\_withparsetree** to true)  
Generates a parse tree at the end of the parse. This parse tree, which is printed in a pseudo-graphical tree view, represents the structure of the complete parsed input splitted into all the used productions and tokens at the leafes of the tree.

To switch the debugging facilities on, set the variables in the brackets above to **true** before invoking the parser entry function. The **##PREFIX##** will be replaced by the optionally defined prefix you set when calling JS/CC.

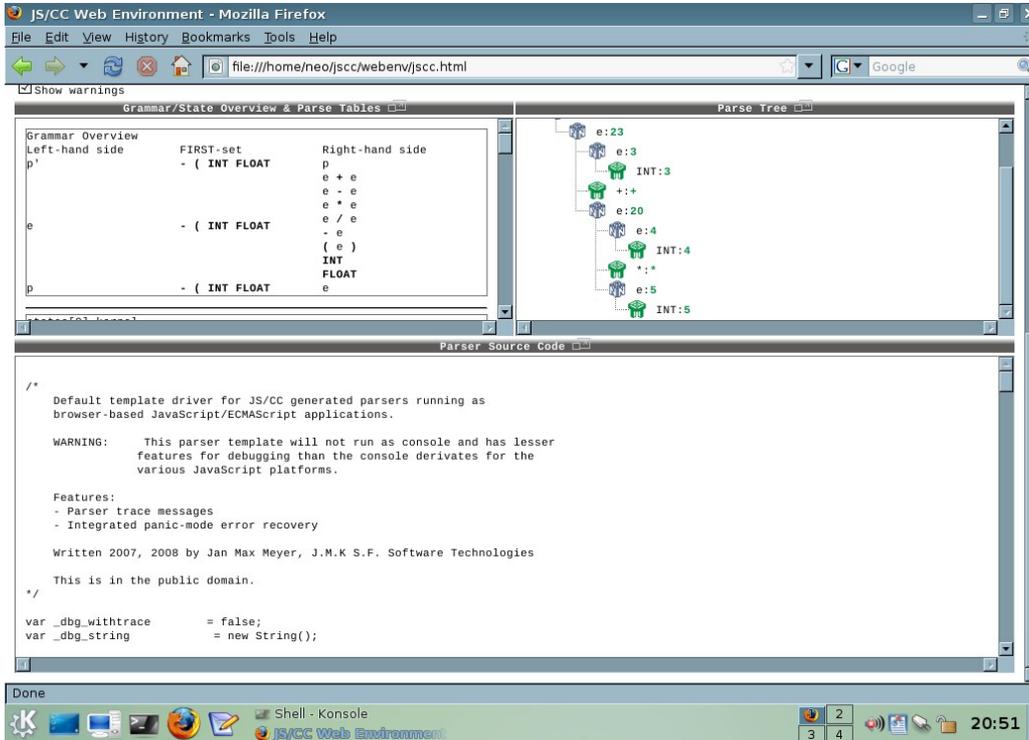
The following table gives a short overview about each template and the supported debug features.

| <i>Driver/File</i> | <i>Platform</i>   | <i>Trace</i> | <i>StepByStep</i> | <i>ParseTree</i> |
|--------------------|---|--------------|-------------------|------------------|
| driver_rhino.js_   | Mozilla/Rhino   | X            | X                 | X                |
| driver_sm.js_      | Mozilla/Spidermonkey  | X            |                   | X                |
| driver_jscript.js_ | Microsoft JScript (WSH)<br>Microsoft JScript.NET                    | X            | X                 | X                |
| driver_v8.js_      | Google V8   | X            | X                 | X                |
| driver_web.js_     | Platform-independent<br>JavaScript                                  | X            |                   |                  |
| driver_webenv.js_  | Platform-independent<br>JavaScript for the JS/CC<br>Web Environment |              |                   | X<br>(always)    |

Table 2: Default parser drivers

## Debugging with the Web Environment

When using the Web Environment, JS/CC automatically provides a parser that constructs a visual parse tree out of the parser's input. This parse tree looks much nicer than the pseudo-graphical one that is printed on the console. The Web Environment uses a modified version of the web-driver, so debug must not be explicitly be enabled – it is always turned on.



Screenshot 5: Graphical parse tree feature in Web Environment

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## Credits

Thanks a lot to Louis P. Santillan for his efforts in porting JS/CC to several platforms and for his help on the project!



*A salute to all that real coders in the world  
from Jan Max and Fynn!*