

Building parsers in JavaScript

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Agenda

- What is parsing?
- Fractions
- Nearley
- Example: Fraction calculator



Rajiv Patel, <https://tinyurl.com/yx6rmcdt>

What is parsing?

You know the problem

- What is syntax?
- How is the syntax defined?
- How do you check if input matches syntax?
- How can you use the syntax in your applications?

(AN UNMATCHED LEFT PARENTHESIS
CREATES AN UNRESOLVED TENSION
THAT WILL STAY WITH YOU ALL DAY.)

<https://xkcd.com/859/>

```
✓ ~
12:13 $ cat foobar.js
function add2(n) {
  return n + ;
}

const a = [1, 2, 3];
let b = a.map(n => add2(n));
console.log(b);

✓ ~
12:13 $ node foobar.js
/Users/kneth/foobar.js:2
  return n + ;
            ^

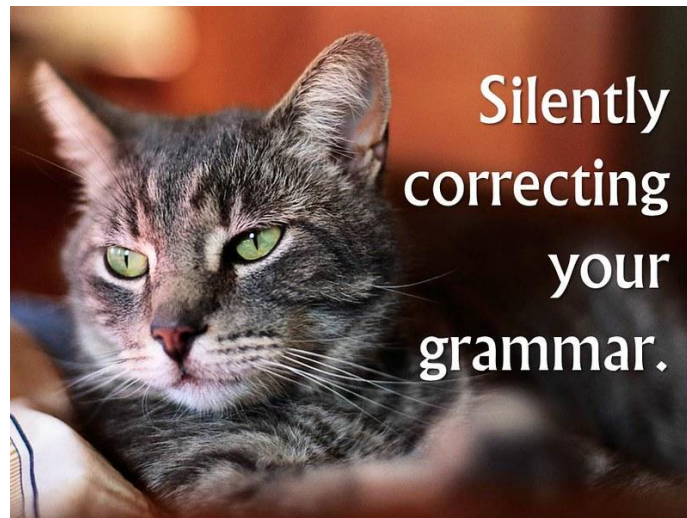
SyntaxError: Unexpected token ;
    at Module._compile (internal/modules/cjs/loader.js:723:23)
    at Object.Module._extensions..js (internal/modules/cjs/loader.js:789:10)
    at Module.load (internal/modules/cjs/loader.js:653:32)
    at tryModuleLoad (internal/modules/cjs/loader.js:593:12)
    at Function.Module._load (internal/modules/cjs/loader.js:585:3)
    at Function.Module.runMain (internal/modules/cjs/loader.js:831:12)
    at startup (internal/bootstrap/node.js:283:19)
    at bootstrapNodeJSCore (internal/bootstrap/node.js:623:3)
```

Grammar

- The syntax is defined by a grammar
- Lexical analysis breaks down input into tokens or terminals
 - Keywords, literals, identifiers, operators
- A set of rules connecting non-terminals to tokens
- One non-terminal is the start symbol
- Parsers are software which use a grammar to verify input

```
function add2(n) {  
  let r = n + 2;  
  return r;  
}
```

keyword Body: statements identifier literal



Silently
correcting
your
grammar.

Ken Whytock, <https://tinyurl.com/s9s3eee>

Example

- $S \rightarrow AA$
- $A \rightarrow a$
- $A \rightarrow \beta$

Matches aa , $a\beta$, βa , and $\beta\beta$

Parser generators

- Many well-documented algorithms exist
 - Hot research topics in 1960s and 1970s
- It's not a trivial task to write a parser
- Parser generators can speed up development process
 - Yacc (C) - 1975!!
 - ANTLR (mostly Java) - 1989
 - Nearley (JavaScript) - 2014



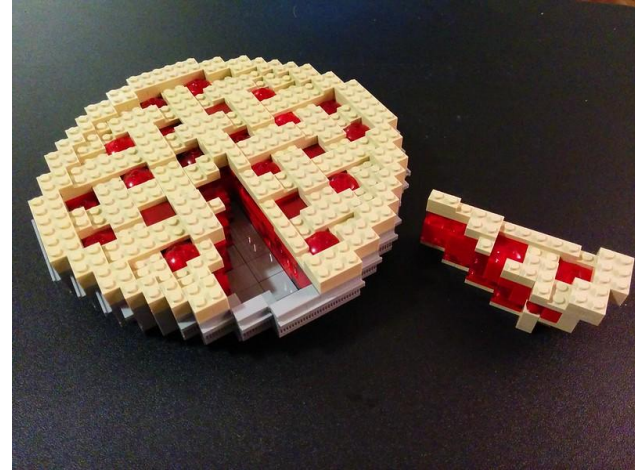
Erica Zabowski, <https://tinyurl.com/uqbaldv>

Fractions

Quick recap

- A fraction is a rational number
 - Numerator and denominator, both natural numbers
 - Broken latin (fractus, broken)
- Fractions are rational numbers

$$\frac{a}{b} \text{ where } b \neq 0$$



Bill Ward, <https://tinyurl.com/r3dtp2b>

Arithmetic

$$f_1 + f_2 = f_2 + f_1$$

$$f_1 \cdot f_2 = f_2 \cdot f_1$$

$$\frac{a_1}{b_1} \pm \frac{a_2}{b_2} = \frac{a_1 \cdot b_2 \pm a_2 \cdot b_1}{b_1 \cdot b_2}$$

$$\frac{a_1}{b_1} \cdot \frac{a_2}{b_2} = \frac{a_1 \cdot a_2}{b_1 \cdot b_2}$$

$$\frac{a_1}{b_1} / \frac{a_2}{b_2} = \frac{a_1 \cdot b_2}{b_1 \cdot a_2}$$

$$\frac{n \cdot a}{n \cdot b} = \frac{a}{b}$$

Greatest Common Divisor

- Original algorithm by Euclid (c. 300 BC)
- Often used to reduce or simplify a fraction
- https://en.wikipedia.org/wiki/Greatest_common_divisor

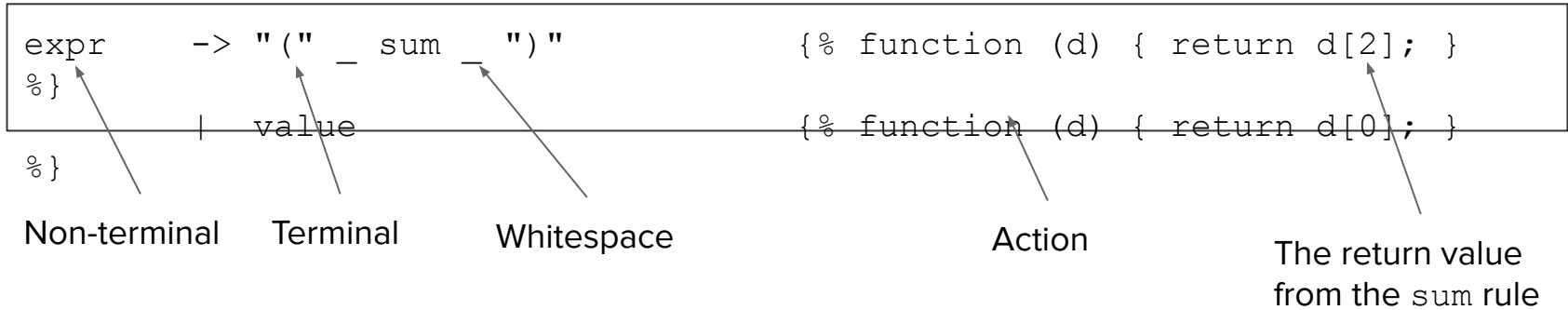
Nearley

Earley Parsers in JavaScript

- Nearley implements Earley's parser algorithm
 - Left-recursive (LR) grammars
 - Deterministic parser
 - Worst-case performance $O(n^3)$ but $O(n)$ for well-behaving grammars
 - https://en.wikipedia.org/wiki/Earley_parser
- Can generate JavaScript, CoffeeScript, and TypeScript
 - Can run in browsers, node.js and probably React Native
- Inclusion of predefined grammars
 - Numbers, white spaces, strings
- Lexer is also included
 - Define tokens using double-quotes
- Rules can have (semantic) actions
 - Plain JavaScript functions

How to use

- Easy installation: `npm install nearley --save-dev`
- Generate a parser: `npx nearleyc -o parser.js parser.ne`
 - Add to scripts in `package.json`
- The `.ne` files contains rules, terminals, non-terminals, and actions

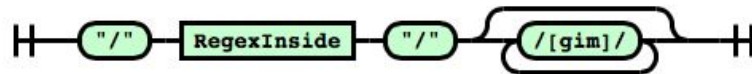


Additional tools

Supported by many editors

- VS Code, Atom, Emacs, Vim, Sublime

Railroad diagrams



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CHANGELOG.md
13
14 @builtin "whitespace.ne" # "." means arbitrary amount of whitespace
15 @builtin "number.ne" # "int", "decimal", and "percentage" number primitives
16
17 @%
18 const Fraction = require('./fraction');
19 %
20
21 # start
22 main → sum { function (d) { return d[0]; } % }
23
24 # parenthesis
25 expr → "*" _ sum _ ")" { function (d) { return d[2]; } % }
26 | value { function (d) { return d[0]; } % }
27
28
29 # multiplication and division
30 product → product _ "*" _ expr { function (d) { return d[0].mul(d[4]); } % }
31 | product _ "/" _ expr { function (d) { return d[0].div(d[4]); } % }
32 | expr { function (d) { return d[0]; } % }
33
34 # addition and subtraction
35 sum → sum _ "+" _ expr { function (d) { return d[0].add(d[4]); } % }
36 | sum _ "-" _ expr { function (d) { return d[0].sub(d[4]); } % }
37 | product { function (d) { return d[0]; } % }
38
39 # a fraction or a number
40 value → fraction { function (d) { return d[0]; } % }
41 | int { function (d) { return new Fraction(d[0], 1); } % }
42
43
44 # a fraction
45 fraction → int _ "/" _ int { function (d) { return new Fraction(d[0], d[4]); } % }
```

```
parser.ne
14 This program is free software: you can redistribute it and/or modify
15 # it under the terms of the GNU General Public License as published by
16 # the Free Software Foundation, either version 3 of the License, or
17 # (at your option) any later version.
18
19 #
20 # This program is distributed in the hope that it will be useful,
21 # but WITHOUT ANY WARRANTY; without even the implied warranty of
22 # MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the
23 # GNU General Public License for more details.
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Example: Fraction calculator

calculator

- Simple Fraction class
 - Basic arithmetic and simplification
- Parser
 - Actions to perform calculation
- Little driver to read input and call parser

```
✓ ~/Projects/calculator [master|✓]
```

```
17:29 $ ./kalc "2/3 * (5/7 + 8/17)"
```

```
2/3 * (5/7 + 8/17) = 94/119
```

```
✓ ~/Projects/calculator [master|✓]
```

```
17:30 $ ./kalc "(2/3 + 9/2) * (7/8 + 1/2 + 3/4)"
```

```
(2/3 + 9/2) * (7/8 + 1/2 + 3/4) = 527/48
```

```
✓ ~/Projects/calculator [master|✓]
```

```
17:30 $ ./kalc "(2/3 - 1/4) * (9/2 + 8/7 + 10/11) / (3/4 - 2/5)"
```

```
(2/3 - 1/4) * (9/2 + 8/7 + 10/11) / (3/4 - 2/5) = 25225/3234
```

The grammar (no actions)

```
main → sum
expr → ( sum )
      | value
product → product * expr
        | product / expr
        | value
sum → sum + expr
     | sum - expr
     | product
value → fraction
      | int
fraction → int / int
```

Start symbol: `main`

Tokens: `(,), +, -, *, /`

Positive integer: `int`

Important take-aways

- Recursive rules
- Operator precedence

Source code: parser.ne

```
@builtin "whitespace.ne" # ` _ ` means arbitrary amount of whitespace
@builtin "number.ne"    # `int`, `decimal`, and `percentage` number primitives

@{%
const Fraction = require('./fraction');
%}

# start
main    → sum                                {% function (d) { return d[0]; } %}

# parenthesis
expr    → "(" _ sum _ ")"                    {% function (d) { return d[2]; } %}
        | value                               {% function (d) { return d[0]; } %}

# multiplication and division
product → product _ "*" _ expr               {% function (d) { return d[0].mul(d[4]); } %}
        | product _ "/" _ expr              {% function (d) { return d[0].div(d[4]); } %}
        | expr                               {% function (d) { return d[0]; } %}

# addition and subtraction
sum     → sum _ "+" _ expr                   {% function (d) { return d[0].add(d[4]); } %}
        | sum _ "-" _ expr                  {% function (d) { return d[0].sub(d[4]); } %}
        | product                           {% function (d) { return d[0]; } %}

# a fraction or a number
value   → fraction                           {% function (d) { return d[0]; } %}
        | int                               {% function (d) { return new Fraction(d[0], 1); } %}

# a fraction
fraction → int _ "/" _ int                   {% function (d) { return new Fraction(d[0], d[4]); } %}
```

Source code: kalc.js

```
const process = require('process');

const nearley = require("nearley");
const parser = require("./parser.js");

const p = new nearley.Parser(nearley.Grammar.fromCompiled(parser));
if (process.argv.length === 3) {
  const expr = process.argv[2];
  p.feed(expr);
  console.log(`${expr} = ${p.results[0].toString()}`);
} else {
  console.error(`Missing expression.`);
}
```

Resources

Links

- My example: <https://github.com/kneth/kalculator>
- Nearley: <https://nearley.js.org/>

- Earley parsers explained: <http://loup-vaillant.fr/tutorials/earley-parsing/>
- An Efficient Context-Free Parsing Algorithm. Jay Earley's Ph.D. thesis from 1968.
<http://reports-archive.adm.cs.cmu.edu/anon/anon/usr/ftp/scan/CMU-CS-68-earley.pdf>

**Building parsers
for JavaScript is
easy - and fun**



¿Fue algo no dicho?

@ronmader

