怎样写一个解释器

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Interpreter

什么是解释器

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解释器是一个不需要将代码编译成机器码，就可以直接解释、执行程序（脚本）语言的程序。
常见的有 ruby, python, php, bc

Interpreter

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解释器是一个不需要将代码编译成机器码，就可以直接解释、执行程序（脚本）语言的程序。
常见的有 ruby, python, php, bc

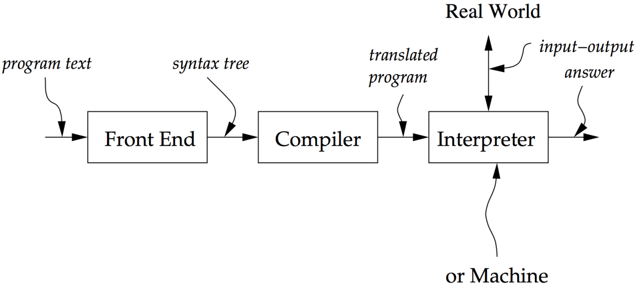
一般启动之后会有一个 提示符，等待用户输入。例如：

```
~ [liszt@liszts-MacBook-Pro]
# racket
Welcome to Racket v6.0.
>
```

Interpreter

Interpreter vs. Compiler

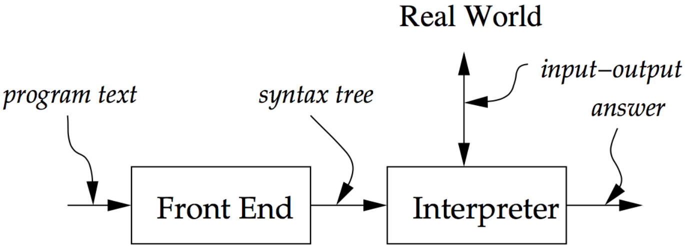
常见的计算机语言需要使用编译器(e.g. gcc, g++)



Interpreter

Interpreter vs. Compiler

解释器的步骤，稍微简单一些：



Front End

Front end vs. Interpreter

Front End

- 作用是把程序代码转换为 AST
- 通常分为 scanning & parsing 两部分
- Scanning 将“字符串”转换成一个 token 序列，token 可能是 单词、数字、注释……
- Parsing 将 token 序列组织为一个 AST
- Front End 读入的语言叫做“source language”
- Concrete Syntax

Front End

Front end vs. Interpreter

Scan & Parse

```
# racket
Welcome to Racket v6.0.
> (require "diff.scm")
> (just-scan "-(5, 8)")
'((literal-string34 "-" 1)
  (literal-string34 "(" 1)
  (number 5 1)
  (literal-string34 "," 1)
  (number 8 1)
  (literal-string34 ")" 1))
> (scan&parse "-(5, 8)")
(a-program (diff-exp (const-exp 5) (const-exp 8)))
```

Front End

Front end vs. Interpreter

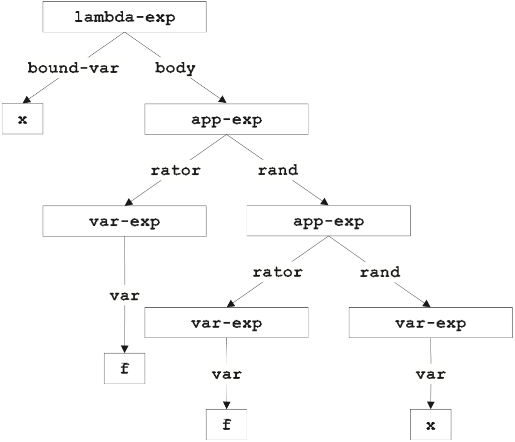
Concrete Syntax

```scheme
(lambda (x)
        (f (f x)))
```

Front End

Front end vs. Interpreter

Abstract Syntax

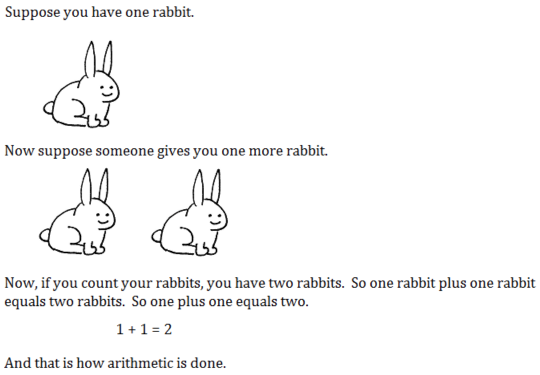


Interpreter 的工作流程是这样的：

- 输入是一个 AST
- Interpreter 根据 AST 的数据结构，执行后续操作
- 实现 Interpreter 的语言，叫做 “implementation language”

Arithmetic for Beginners

Interpreter



Suppose you have one rabbit.

Now suppose someone gives you one more rabbit.

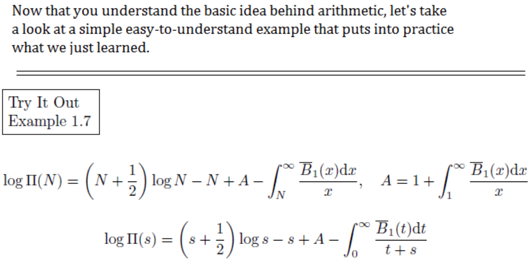
Now, if you count your rabbits, you have two rabbits. So one rabbit plus one rabbit equals two rabbits. So one plus one equals two.

1 + 1 = 2

And that is how arithmetic is done.

Arithmetic for Beginners

Interpreter



Now that you understand the basic idea behind arithmetic, let's take a look at a simple easy-to-understand example that puts into practice what we just learned.

Try It Out
Example 1.7

$$\log \Pi(N) = \left(N + \frac{1}{2}\right)\log N - N + A - \int_N^\infty \frac{\overline{B}_1(x)\mathrm{d}x}{x}, \quad A = 1 + \int_1^\infty \frac{\overline{B}_1(x)\mathrm{d}x}{x}$$

$$\log \Pi(s) = \left(s + \frac{1}{2}\right)\log s - s + A - \int_0^\infty \frac{\overline{B}_1(t)\mathrm{d}t}{t+s}$$

功能简介

写一个解释器

下面我们写一个简单的解释器，它只有一个功能： 读入用户输入的字符串，并且输出一个数字

类似于这样:

```
# racket
Welcome to Racket v6.0.
> (require "const.scm")
> (run "89")
(num-val 89)
> (run "64")
(num-val 64)
```

功能简介

写一个解释器

Syntax:

Program ::= Expression

a-program (exp1)

Expression ::= Number

const-exp (num)

Front End

写一个解释器

Syntax:

```scheme
(define the-lexical-spec
  `((whitespace (whitespace) skip)
    (number (digit (arbno digit)) number)
    (number ("-" digit (arbno digit)) number)
    ))

(define the-grammar
  `((program (expression) a-program)
    (expression (number) const-exp)
    ))
```

Front End

写一个解释器

使用 “sllgen”, 可以完成 字符串到 AST 的转换:

```
# racket
Welcome to Racket v6.0.
> (require "const.scm")
> (scan&parse "89")
(a-program (const-exp 89))
> (scan&parse "64")
(a-program (const-exp 64))
```

Interpreter

写一个解释器

解释器部分需要处理 Program 和 Expression

Pragram

```
(define value-of-program
  (lambda (pgm)
    (cases program pgm
      (a-program (exp1)
                 (value-of exp1 (init-env))))))
```

Expression

```
(define value-of
  (lambda (exp env)
    (cases expression exp
      (const-exp (num) (num-val num)))))
```

执行结果

写一个解释器

下面执行几段代码：

```
# racket
Welcome to Racket v6.0.
> (require "const.scm")
> (run "89")
(num-val 89)
> (run "64")
(num-val 64)
```

增加功能

写一个解释器

下面我们为解释器增加 diff 、if 操作

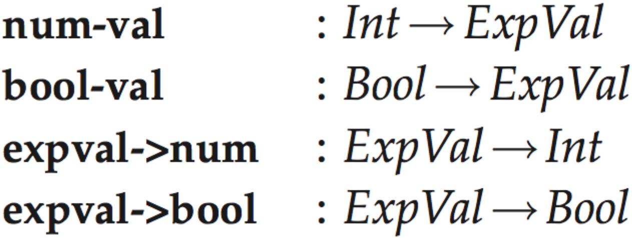
定义数据类型：

```
(define-datatype expval expval?
  (num-val
   (value number?))
  (bool-val
   (boolean boolean?)))
```

增加功能

写一个解释器

由于计算需要在数字之间进行，if 需要布尔类型，所以需要它们到 AST 之间转换的方法



$$
\begin{array}{ll}
\textbf{num-val} & : \mathit{Int} \longrightarrow \mathit{ExpVal} \\
\textbf{bool-val} & : \mathit{Bool} \longrightarrow \mathit{ExpVal} \\
\textbf{expval->num} & : \mathit{ExpVal} \longrightarrow \mathit{Int} \\
\textbf{expval->bool} & : \mathit{ExpVal} \longrightarrow \mathit{Bool}
\end{array}
$$

diff

写一个解释器

Syntax:

Program ::= -(Expression , Expression)

diff-exp (exp1 exp2)

Front End

```
(define the-grammar
  `((program (expression) a-program)
    (expression (number) const-exp)
    (expression
     ("-" "(" expression "," expression ")")
     diff-exp)
    ))
```

diff

写一个解释器

Interpreter

```
(define value-of
  (lambda (exp env)
    (cases expression exp
      (const-exp (num) (num-val num))
      (diff-exp (exp1 exp2)
                (let ((val1 (value-of exp1 env))
                      (val2 (value-of exp2 env)))
                  (let ((num1 (expval->num val1))
                        (num2 (expval->num val2)))
                    (num-val
                     (- num1 num2)))))
)))
```

zero?, if

写一个解释器

Syntax:

Program ::= zero? (Expression)

zero?-exp (exp1)

Program ::= if Expression then Expression else Expression

if-exp (exp1 exp2 exp3)

zero?、if

写一个解释器

Front End

```
(define the-grammar
  `((program (expression) a-program)
    (expression
     ("zero?" "(" expression ")")
     zero?-exp)

    (expression
     ("if" expression "then" expression "else"
        expression)
     if-exp)
    ))
```

zero?、if

写一个解释器

Interpreter

```
(define value-of
  (lambda (exp env)
    (cases expression exp
      (zero?-exp (exp1)
                 (let ((val1 (value-of exp1 env)))
                   (let ((num1 (expval->num val1)))
                     (if (zero? num1)
                         (bool-val #t)
                         (bool-val #f)))))
      (if-exp (exp1 exp2 exp3)
              (let ((val1 (value-of exp1 env)))
                (if (expval->bool val1)
                    (value-of exp2 env)
                    (value-of exp3 env))))
)))
```

执行结果

写一个解释器

下面执行几段代码：

```
# racket
Welcome to Racket v6.0.
> (require "diff.scm")
> (run "-(89, 64)")
(num-val 25)
> (run "if zero? (-(89, 64)) then 0 else 1")
(num-val 1)
```

Variable

写一个解释器

表达式中的变量，需要在一个“环境”去求值才有意义(变量的具体值存储在环境中)

一个环境有三个最基本的操作:

- empty-env 初始化一个 environment
- extend-env 绑定一对变量，并返回绑定后的 environment
- apply-env 从环境中读取变量的值

Let

写一个解释器

Syntax:

Program ::= let Identifier = Expression in Expression

let-exp (var exp1 body)

Front End

```
(define the-grammar
  `((expression
     ("let" identifier "=" expression "in" expression)
     let-exp)
    ))
```

Let

写一个解释器

Interpreter

```
(define value-of
  (lambda (exp env)
    (cases expression exp
      (let-exp (var exp1 body)
               (let ((val1 (value-of exp1 env)))
                 (value-of body
                           (extend-env var val1
                              env))))
)))
```

执行结果

写一个解释器

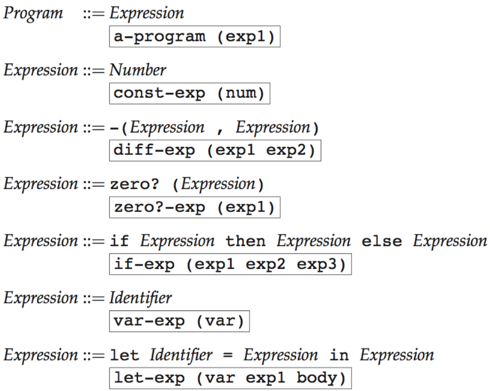
下面执行几段代码：

```
# racket
Welcome to Racket v6.0.
> (require "diff.scm")
> (run "let x = 89 in x")
(num-val 89)
> (run "let x = 0 in if zero?(x) then 0 else 1")
(num-val 0)
```

解释器语法

写一个解释器

汇总一下前面这个解释器支持的语法：



Program ::= *Expression*
`a-program (exp1)`

Expression ::= *Number*
`const-exp (num)`

Expression ::= `-(`*Expression* `,` *Expression*`)`
`diff-exp (exp1 exp2)`

Expression ::= `zero?` `(`*Expression*`)`
`zero?-exp (exp1)`

Expression ::= `if` *Expression* `then` *Expression* `else` *Expression*
`if-exp (exp1 exp2 exp3)`

Expression ::= *Identifier*
`var-exp (var)`

Expression ::= `let` *Identifier* `=` *Expression* `in` *Expression*
`let-exp (var exp1 body)`

ToDo

后续你可以继续为这个解释器添加以下功能，来得到一门基本可用的语言：

- 函数
- 递归
- 各种语法糖

QA

写一个解释器

ref:

- http://www.eopl3.com/
- https://mitpress.mit.edu/sicp/
- http://docs.racket-lang.org/eopl/index.html?q=