

YuchiKaml

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## 1 Introduction

YuchiKaml is a toy language. and YuchiKaml interpreter is an implementation of interpreter of YuchiKaml. Both are created in order to get accustomed to Sprache, a C#Parser Combinator Library. In this article, I introduce both the language and the interpreter.

## 2 YuchiKaml Language

YuchiKaml is a dynamic typed language with-ML like surface grammar.

### 2.1 Syntax

In this section, we define the syntax of YuchikiML.

#### 2.1.1 Expression

*Expressions* of YuchiKaml are defined by the following BNF equations:

$$\begin{aligned}
e ::= & () \mid x \mid n \mid \text{true} \mid \text{false} \mid s \mid (e) \\
& \mid e \ e \mid !e \\
& \mid e * e \mid e / e \\
& \mid e + e \mid e - e \\
& \mid e \leq e \mid e < e \mid e \geq e \mid e > e \\
& \mid e = e \mid e \neq e \\
& \mid e \& e \\
& \mid e \parallel e \\
& \mid e \triangleright e \mid e \gg e \\
& \mid \text{if } e \text{ then } e \text{ else } e \mid \text{let } x \ \tilde{a} = e \text{ in } e \mid \text{let rec } f \ a_1 \ \tilde{a} = e \text{ in } e \mid \lambda x. e \\
& \mid e ; e
\end{aligned}$$

The operators defined in earlier rows have stronger precedences than the operators defined in later rows. For example,  $1 + 2 * 3$  is not parsed as  $(1 + 2) * 3$ , but  $1 + (2 * 3)$ .

**Example 2.1** (GCD). This is an example of a YuchiKaml source code of a program which calculates the greatest common divisor of 120 and 45.

Listing 1: gcd

```

let rec gcd m n =
  if m > n then gcd (m - n) n
  else if m < n then gcd m (n - m)
  else m
in gcd 120 45

```

### 2.1.2 Syntax Sugar

Some of the expressions shown above are syntactic sugars. We show the list and syntax sugars and how they are desugared.

$$\begin{aligned}
e_1 \triangleright e_2 &::= e_2 \ e_1 \\
e_1 \gg e_2 &::= \lambda x. g(fx) \\
\text{let } f \ a_1 \cdots a_n = e_1 \text{ in } e_2 &::= \text{let } f = \lambda a_1. \cdots \lambda a_n. e_1 \text{ in } e_2 \\
\text{let rec } f \ a \ b_1 \cdots b_n = e_1 \text{ in } e_2 &::= \text{let rec } f \ a = \lambda b_1. \cdots \lambda b_n. e_1 \text{ in } e_2 \\
e_1 ; e_2 &::= \text{let } \_ = e_1 \text{ in } e_2
\end{aligned}$$

The semantics of expressions, introduced in a later section, is defined for desugared expressions.

### 2.1.3 real notation

In real source codes, the symbols above are notated as follows:

$\leq$	$<=$
$\geq$	$>=$
$\neq$	$!=$
$\&\&$	$\&\&$
$\parallel$	$\parallel$
$\triangleright$	$ >$
$>>$	$>>$
$\lambda x. e$	$\backslash x - > e$

## 2.2 Semantics

Then we define the semantics of expressions. We assume that the behaviour of built-in functions are given. That is, built-in functions are assumed deterministic.

### 2.2.1 Value

*Values* of expressions are listed as below:

$$\begin{aligned}
 v(\text{value}) &::= n \mid b \mid s \mid \text{cl} \mid f_b \\
 \rho(\text{valuation}) &\in \text{Var} \not\rightarrow \text{Val} \\
 f_b(\text{built-in function}) &\in \text{His} \times \text{Val} \not\rightarrow \text{Val} \\
 \text{cl}(\text{closure}) &::= (x, e, \rho) \\
 h(\text{history}) &::= \langle (f_1, v_1); \dots; (f_n, v_n) \rangle
 \end{aligned}$$

Here Var is the set of the variables and Val is the set of the values.

**Note 2.1.** We assume that all the built-in functions return the same value for the same input, if it does not diverge. This is enough to see whether different two ways of execution of a program is equivalent or not, given a situation.

### 2.2.2 Small-Step Evaluation

We have to define the behaviour of evaluation process of expressions clearly. To this end, we define the *evaluation* process of expression by a big-step semantics shown below.

An *evaluation relation* is a four-term relation of the form  $\rho \vdash h; e \longrightarrow h'; v$ . The evaluation rules of YuchiKaml are shown below:

$$\begin{array}{c}
\frac{}{\rho \vdash h; x \longrightarrow h; \rho(x)} \quad (\text{E-VAR}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; (x, e'_1, \rho') \quad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1 \ e_2 \longrightarrow h'''; v'_1} \quad (\text{E-APP}) \\
\\
\frac{\rho \vdash h; e \longrightarrow h'; b}{\rho \vdash h; !e \longrightarrow h'; \llbracket ! \rrbracket b} \quad (\text{E-NOT}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 * e_2 \longrightarrow h''; n_1 \llbracket * \rrbracket n_2} \quad (\text{E-MUL}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 / e_2 \longrightarrow h''; n_1 \llbracket / \rrbracket n_2} \quad (\text{E-DIV}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 + e_2 \longrightarrow h''; n_1 \llbracket + \rrbracket n_2} \quad (\text{E-PLUS}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 - e_2 \longrightarrow h''; n_1 \llbracket - \rrbracket n_2} \quad (\text{E-MINUS}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 \leq e_2 \longrightarrow h''; n_1 \llbracket \leq \rrbracket n_2} \quad (\text{E-LEQ}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 < e_2 \longrightarrow h''; n_1 \llbracket < \rrbracket n_2} \quad (\text{E-LT}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 \geq e_2 \longrightarrow h''; n_1 \llbracket \geq \rrbracket n_2} \quad (\text{E-GEQ}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 > e_2 \longrightarrow h''; n_1 \llbracket > \rrbracket n_2} \quad (\text{E-GT}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; v_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1 = e_2 \longrightarrow h''; v_1 \llbracket = \rrbracket v_2} \quad (\text{E-EQ}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; v_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1 \neq e_2 \longrightarrow h''; v_1 \llbracket \neq \rrbracket v_2} \quad (\text{E-NEQ}) \\
\\
\frac{\rho \vdash h; e_1 \longrightarrow h'; b_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; b_2}{\rho \vdash h; e_1 \ \&\& \ e_2 \longrightarrow h''; v_1 \llbracket \&\& \rrbracket v_2} \quad (\text{E-AND})
\end{array}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; b_1 \quad \rho \vdash h'; e_2 \longrightarrow h''; b_2}{\rho \vdash h; e_1 \parallel e_2 \longrightarrow h''; v_1 \llbracket \rrbracket v_2} \quad (\text{E-OR})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; \text{true} \quad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \longrightarrow h''; v_2} \quad (\text{E-IF-TRUE})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; \text{false} \quad \rho \vdash h'; e_3 \longrightarrow h''; v_3}{\rho \vdash h; \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \longrightarrow h''; v_3} \quad (\text{E-IF-FALSE})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; v_1 \quad \rho \cup \{x \mapsto v_1\} \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; \text{let } x = e_1 \text{ in } e_2 \longrightarrow h''; v_2} \quad (\text{E-LET})$$

$$\frac{\mu X. \rho \cup \{f \mapsto (x, e_1, X)\} \vdash h; e_2 \longrightarrow h'; v_2}{\rho \vdash h; \text{let rec } f \ x = e_1 \text{ in } e_2 \longrightarrow h'; v_2} \quad (\text{E-LETREC})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; f_b \quad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1 \ e_2 \longrightarrow \langle h'', (f_b, v_2) \rangle; (f_b h'' v_2)} \quad (\text{E-APPBUILTIN})$$

$$\frac{}{\rho \vdash h; \lambda x. e \longrightarrow h; (x, e, \rho)} \quad (\text{E-ABS})$$

We write  $\llbracket e \rrbracket$  for  $(h, v)$  such that  $\emptyset \vdash \langle \rangle; e \longrightarrow h; v$ .

A *valid execution* of a YuchiKaml program expression  $e$  has the built-in function call history  $h$  and the return value  $v$  such that  $(h, v) = \llbracket e \rrbracket$ .

### 3 YuchiKaml Interpreter

#### 3.1 Usage

#### 3.2 Preprocess