YuchiKaml

Yuchiki

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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

First, we define the expressions of YuchikiML.

Definition 1 (surface expression)**.** A *surface expression* of YuchiKaml is defined by the following BNF equations:

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

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 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 Actual Notation

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

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

2.1.3 Comment

YuchiKaml has two kinds of comments.

Line Comment: Characters from *//* to the end of line are ignored.

Bracket Comment: Characters from *(** to **)* are ignored.

2.1.4 Syntax Sugar

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

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

Definition 2 (expression)**.** We call a desugared surface expression as just *expression.*

The semantics of expressions, introduced in a later section, is defined for *expressions*, not *surface expressions.*

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:

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

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

Note 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 weather different two ways of execution of a program is equivalent or not ,given a situation.

2.2.2 Evaluation Relation

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:

$$\frac{}{\rho \vdash h; x \longrightarrow h; \rho(x)} \quad \text{(E-Var)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; (x, e_1', \rho') \qquad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1\ e_2 \longrightarrow h'''; v_1'} \quad \text{(E-App)}$$

$$\frac{\rho \vdash h; e \longrightarrow h'; b}{\rho \vdash h; !e \longrightarrow h';\ [\![!]\!]\, b} \quad \text{(E-Not)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 * e_2 \longrightarrow h''; n_1\, [\![*]\!]\, n_2} \quad \text{(E-Mul)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 / e_2 \longrightarrow h''; n_1\, [\![/]\!]\, n_2} \quad \text{(E-Div)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 + e_2 \longrightarrow h''; n_1\, [\![+]\!]\, n_2} \quad \text{(E-Plus)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 - e_2 \longrightarrow h''; n_1\, [\![-]\!]\, n_2} \quad \text{(E-Minus)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 \leq e_2 \longrightarrow h''; n_1\, [\![\leq]\!]\, n_2} \quad \text{(E-Leq)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 < e_2 \longrightarrow h''; n_1\, [\![<]\!]\, n_2} \quad \text{(E-Lt)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 \geq e_2 \longrightarrow h''; n_1\, [\![\geq]\!]\, n_2} \quad \text{(E-Geq)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; n_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; n_2}{\rho \vdash h; e_1 > e_2 \longrightarrow h''; n_1\, [\![>]\!]\, n_2} \quad \text{(E-Gt)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; v_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1 = e_2 \longrightarrow h''; v_1\, [\![=]\!]\, v_2} \quad \text{(E-Eq)}$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; v_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; e_1 \neq e_2 \longrightarrow h''; v_1 \, [\![\neq]\!] \, v_2} \quad (\text{E-Neq})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; b_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; b_2}{\rho \vdash h; e_1 \,\&\&\, e_2 \longrightarrow h''; v_1 \, [\![\&\&]\!] \, v_2} \quad (\text{E-And})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; b_1 \qquad \rho \vdash h'; e_2 \longrightarrow h''; b_2}{\rho \vdash h; e_1 \,||\, e_2 \longrightarrow h''; v_1 \, [\![||]\!] \, v_2} \quad (\text{E-Or})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; \mathrm{true} \qquad \rho \vdash h'; e_2 \longrightarrow h''; v_2}{\rho \vdash h; \mathrm{if}\, e_1 \,\mathrm{then}\, e_2 \,\mathrm{else}\, e_3 \longrightarrow h''; v_2} \quad (\text{E-If-True})$$

$$\frac{\rho \vdash h; e_1 \longrightarrow h'; \mathrm{false} \qquad \rho \vdash h'; e_3 \longrightarrow h''; v_3}{\rho \vdash h; \mathrm{if}\, e_1 \,\mathrm{then}\, e_2 \,\mathrm{else}\, e_3 \longrightarrow h''; v_3} \quad (\text{E-If-False})$$

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

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

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

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

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

2.2.3 Valid Execution

The evaluation process shown above is just one of the ways of possible evaluations. Real Implementation of YuchiKaml may be done in a more optimized way, or in av completely different way which gives the result equivalent to that of the process in Section 2.2.2. We define the valid ways of executions using the evaluation relation.

Definition 3 (valid execution)**.** Assume that the behaviour of built-in functions are already given. An execution of a YuchiKaml expression e, which has the history h of built-in function calls and the return value v, is *valid* if $(h, v) = [\![e]\!]$.

3 YuchiKaml Interpreter

3.1 Usage

3.2 Preprocess