Sample Midterm Exam

CS 320, Fall 2018

Student id: _____ Name: _____

Instructions: You have 180 minutes to complete this closed-book, closed-note, closed-computer exam. Please write all answers in the provided space. Korean students should write your answers in Korean.

This sample has less than a half of the actual midterm exam.

1) **(5pts)** Different programming languages have different purposes and target application domains, which lead them to make different design choices. For 2 programming languages of your choice not from this course like `FAE` and `BMFAE` but from real world like C, Racket, Kotlin, Python, OCaml, Haskell, and Scala, compare their pros and cons clearly.

2) **(5pts)** Explain what first-class functions are and write a code example that uses a first-class function in your favorite language (Rust, JavaScript, `RCFAE`, Java, C++, · · ·).

3) **(5pts)** Given the following grammar:

```
<WAE> ::= <num>
        | {+ <WAE> <WAE>}
        | {* <WAE> <WAE>}
        | {let {<id> <WAE>} <WAE>}
        | <id>
```

where `<num>` denotes numbers and `<id>` denotes identifiers that are disjoint with numbers. Describe whether each of the following is `<WAE>` and why:

a) `{let {x 5} {+ 8 {* x 2 3}}}`

b) `{with {x 0} {with {x 7}}}`

c) `{let {3 5} {+ 8 {- x 2}}}`

d) `{let {3 y} {+ 8 {* x 2}}}`

e) `{let {x y} {+ 8 {* x 2}}}`

4) **(5pts)** The following code is a partial implementation of the interpreter for `RCFAE`:

```
0 // interp : (RCFAE, Env) => RCFAEValue
1 def interp(e: RCFAE, env: Env): RCFAEValue = e match {
2   ...
3   case Rec(f, x, b) =>
4     val cloV = CloV(x, b, env)
5     cloV.env = env + (f -> cloV)
6     cloV
```

Consider the evaluation of the following `RCFAE` expression under the empty environment:

```
{with {count {recfun {count n}
                     {if0 n 0 {+ 1 {count {- n 1}}}}}}
      {count 8}}
```

a) What is the value of `cloV` after evaluating the expression at line 4?

b) What is the value of `cloV` after evaluating the expression at line 5?

c) What is the value of `cloV` after evaluating the expression at line 6?

5) **(5pts)** The following code is an excerpt from the implementation of the interpreter for `BFAE`:

```
// interp : (BFAE, Env, Sto) => (BFAEValue, Sto)
def interp(bfae:BFAE, env:Env, sto:Sto): (BFAEValue, Sto) =
  bfae match { ...
    case App(f, a) =>
      val (fv, fs) = interp(f, env, sto)
      val (av, as) = interp(a, env, fs)
      fv match {
        case CloV(x, b, fenv) =>
          interp(b, fenv + (x -> av), as)
        case _ => error(s"not a closure: $fv")
      }
  }
```

In `BMFAE`, we introduce variables so that `Env` maps names to addresses (integers) and `Sto` maps addresses (integers) to values (`BMFAEValue`). Rewrite the above `app` case for `BMFAE`.

6) **(10pts)** Consider the following language e:

$$
\begin{array}{rcl}
e & ::= & x \\
& | & \lambda x.e \\
& | & e\ e \\
& | & \{f\ e,\ \cdots,\ f\ e\} \\
& | & e.f \\
& | & e; e \\
& | & (e)
\end{array}
$$

where a value of the language is either a record ρ or a closure $\langle \lambda x.e, \sigma \rangle$, and an environment maps names to values:

$$
\begin{array}{lcll}
x & \in & \mathit{Var} & \\
f & \in & \mathit{Field} & \\
\sigma & \in & \mathit{Env} & = \mathit{Var} \xrightarrow{\text{fin}} \mathit{Value} \\
\langle \lambda x.e, \sigma \rangle & \in & \mathit{Closure} & = \mathit{Expr} \times \mathit{Env} \\
\rho & \in & \mathit{Record} & = \mathit{Field} \xrightarrow{\text{fin}} \mathit{Value} \\
v & \in & \mathit{Value} & = \mathit{Closure} + \mathit{Record}
\end{array}
$$

The semantics of some constructs are as follows:

- The value of a record $\{f_1\ e_1,\ \cdots,\ f_k\ e_k\}$ is a finite map ρ, which maps $f_i \in \{f_1\ \cdots,\ f_k\}$ to the value v_i evaluated from the expression e_i.
- The value of $e.f$ is the value of the field f in the record e.
- The semantics of $e_1; e_2$ is to evaluate e_1 first and evaluate e_2 next, which is the value of $e_1; e_2$.
- The value of (e) is the value of e.

a) Write the operational semantics of the form $\boxed{\sigma \vdash e \Rightarrow v}$

b) Write the evaluation derivation of the following expressions:

$$\emptyset \vdash \{f\ \{g\ \lambda x.x\}\}.f \Rightarrow$$