

Assignment 2

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General Instructions

Submit your answers to the theoretical questions in a pdf file called `id1_id2.pdf` and your code for programming questions inside the provided `q2.l3`, and `L31-ast.ts`, `q3.ts`, `q4.ts` files of the `src` folder. ZIP those files together (including the pdf file, and only those files) into a file called `id1_id2.zip`. Make sure that your code abides the Design By Contract methodology.

Do not send assignment related questions by e-mail, use the forum instead. For any administrative issues (milu'im/extensions/etc) please open a request ticket in the Student Requests system.

You are provided with the templates `ex2.zip`.

Unpack the template files inside a folder. From the command line in that folder, invoke `npm install`, and work on the files in that directory, preferably working in the Visual Studio Code IDE (refer to the Useful Links). In order to run the tests, run `npm test` from the command line.

Important: Do not add any extra libraries and do not change the provided `package.json` and `tsconfig.json` configuration files. **The graders will use the exact provided files.** If you find any missing necessary libraries, please let us know.

Question 1: Theoretical Questions [30 points]

Q1.1 Why are special forms required in programming languages? Why can't we simply define them as primitive operators? Give an example [4 points]

Q1.2 Write a program in L1, containing more than one expression, where the evaluation of the program's expression **can be done in parallel** (e.g., the interpreter can run a thread for each expression evaluation).

Write a program in L1, containing more than one expression, where the evaluation of the program's expression **cannot be done in parallel**.

[4 points]

Q1.3 Let us define the L0 language as L1 excluding the special form 'define'. Is there a program in L1 which cannot be transformed to an equivalent program in L0? Explain or give a contradictory example [4 points]

Q1.4 Let us define the L20 language as L2 excluding the special form 'define'. Is there a program in L2 which cannot be transformed to an equivalent program in L20? Explain or give a contradictory example [4 points]

Q1.5 For the following high-order functions in L3, which get a function and a list, indicate (and explain) whether the order of the procedure application on the list items should be sequential or can be applied in parallel:

- map
- reduce
- filter
- all (returns #t is the application of the given boolean function on each of the given list items returns #t)
- compose (compose a given procedure with a given list of procedures)

[10 points]

Q1.6 Regarding L31 language, as defined in **Q3b** (below): what is the value of the following program? Explain.

```
(define b 1)
(define c 2)
(define pair
  (class (a b)
    ((first (lambda () a))
     (second (lambda () b))
     (f (lambda () (+ a b c))))
  )
)

(define p34 (pair 3 4))

(
  (lambda (c) (p34 'f))
  5
)
```

[4 points]

Answers should be submitted in file id1_id2.pdf

Question 2: Programing in L3 [30 points]

Q2.1

Write an L3 procedure *append*, which gets two lists and returns their concatenation. For example:

(append '(1 2) '(3 4)) → '(1 2 3 4)

Q2.2

Write an L3 procedure *reverse*, which gets a list and reverses it. For example:

(reverse '(1 2 3)) → '(3 2 1)

Q2.3

Write an L3 procedure *duplicate-items*, which gets two lists - *lst* , *dup-count* - and duplicates each item of *lst* according to the number defined in the same position in *dup-count*.

In case *dups-count* length is smaller than *lst*, *dup-count* should be treated as a cyclic list.

Examples:

(duplicate-items '(1 2 3) '(1 0))→ '(1 3)

(duplicate-items '(1 2 3) '(2 1 0 10 2))→ '(1 1 2)

You may assume that *dup-count* contains numbers and is not empty.

Q2.4

Write an L3 procedure *payment*, which gets a sum of money and list of available coins, and returns the number of possible ways to pay the money with these coins.

Examples:

(payment 10 '(5 5 10)) → 2

[1 coin of 10 ,2 coins of 5]

(payment 5 '(1 1 1 2 2 5 10)) → 3

[1 coin of 5, 1 coin of 2 and 3 coins of 1, 2 coins of 2 and 1 coin of 1]

Q2.5

Write an L3 procedure *compose-n*, which gets an unary function *f* and a number *n* (>0) and returns the closure of the n-th self-composition of *f*:

For example:

```
(define mul8 (compose-n (lambda (x) (* 2 x)) 3))  
(mul8 3) → 24
```

You may add auxiliary procedures to all questions.

The code (without comments) should be submitted in file src/q2.l3

Don't forget to write a contract for each of the above procedures.

; Signature:

; Type:

; Purpose:

; Pre-conditions:

; Tests:

Write the contracts in file id1_id2.pdf.

You can test your code with test/q2-tests.ts

Question 3: Syntactic Parsing & Transformations [25 points]

Let us define the L31 as L3 with the addition of the special form 'class' for class definition:

A 'class' expression is defined by a list of 'fields' and a list of methods (as bindings - method names and method expressions), as given by the following abstract and concrete syntax:

```
<program> ::= (L31 <exp>+) / Program(exps:List(exp))  
<exp> ::= <define> | <cexp> / DefExp | CExp  
<define> ::= ( define <var> <cexp> ) / DefExp(var:VarDecl,  
val:CExp)  
<var> ::= <identifier> / VarRef(var:string)  
<cexp> ::= <number> / NumExp(val:number)  
          | <boolean> / BoolExp(val:boolean)  
          | <string> / StrExp(val:string)  
          | ( lambda ( <var>* ) <cexp>+ ) / ProcExp(args:VarDecl[],  
          | / body:CExp[]))  
          | ( class ( <var>+ ) ( <binding>+ ) )  
            / ClassExp(fields:VarDecl[], methods:Binding[]))  
          | ( if <cexp> <cexp> <cexp> ) / IfExp(test: CExp,
```

```

|                                     then: CExp,
|                                     alt: CExp)
| ( let ( <binding>* ) <cexp>+ ) /
LetExp(bindings:Binding[],
|                                     body:CExp[]))
| ( quote <sexp> ) / LitExp(val:SExp)
| ( <cexp> <cexp>* ) / AppExp(operator:CExp,
|                                     operands:CExp[]))
<binding> ::= ( <var> <cexp> ) / Binding(var:VarDecl,
|                                     val:Cexp)
<prim-op> ::= + | - | * | / | < | > | = | not | eq? | string=?
| cons | car | cdr | list | pair? | list? | number?
| boolean? | symbol? | string?
<num-exp> ::= a number token
<bool-exp> ::= #t | #f
<str-exp> ::= "tokens*"
<var-ref> ::= an identifier token
<var-decl> ::= an identifier token
<sexp> ::= symbol | number | bool | string | ( <sexp>* )

```

The class Pair in Java, for example, can be defined in L31 with the new special for as follows:

```

// Java
class Pair {
    private int a,b;
    Pair(int a, int b) { this.a = a; this.b = b; }
    int first() { return a; }
    int second() { return b; }
    int sum() { return a + b; }
}

//L31
(define pair
  (class (a b)
    ((first (lambda () a))
     (second (lambda () b))
     (sum (lambda () (+ a b))))
  )
)

```

- a. Add the new 'class' special form to the parser of L31 (the file 'src/L31-ast.ts'):

In order to create an instance of a given class, the class should be ‘applied’ with the parameters for the fields (as done with constructor in languages like Java)

```
// Java
Pair p34 = new Pair(3,4);
```

```
// L31
(define p34 (pair 3 4))
```

In order to call a method in L31, the instance should be applied with a symbol which denote the method:

```
// Java
p34.first();
→ 3
p34.second();
→ 4
p34.sum();
→ 7
```

```
// L31
(p34 `first)
→ 3
(p34 `second)
→ 4
(p34 `add)
→ 7
```

In order to avoid the implementation of the semantics of the ‘class’ form in the interpreter of L31, one of the students suggested transforming a given ‘class’ expression to an equivalent AppExp. The Pair class, for example, can be expressed by the following ProcExp (**for simplicity, we assume that the methods of the class have no parameter, and that #f indicates error in the transformed code as done in the following example**):

```
(define pair
  (lambda (a b)
    (lambda (msg)
      (if (eq? msg 'first)
          ((lambda () a) )
          (if (eq? msg 'second)
              ((lambda () b) )
              (if (eq? msg 'sum)
                  ((lambda () (+ a b)) )
                  #f))))))
```

```
#f))))))
```

- b. Implement the procedure *class2proc* (at file *src/q3.ts*), which applies a syntactic transformation from a *ClassExp* to an equivalent *ProcExp*.

Implement the procedure *L31ToL3* (at file *src/q3.ts*), which gets an L31 AST and returns an equivalent L3 AST.

The code should be submitted in files *src/q3.ts*, *src/L31-ast.ts*

You can test your code with *test/q3-tests.ts*

Question 4: Code translation [15 points]

Write the procedure *l2ToPython* which transforms a given L2 program to a Python program.

For example:

```
(+ 3 5) ⇒ (3 + 5)
```

```
(if (> x 3) 4 5) ⇒ (4 if (x > 3) else 5)
```

```
(lambda (x y) (* x y)) ⇒ (lambda x, y : (x * y))
```

```
((lambda (x y) (* x y)) 3 4) ⇒ (lambda x, y : (x * y))(3,4)
```

```
(define pi 3.14) ⇒ pi = 3.14
```

```
(define f (lambda (x y) (* x y))) ⇒ f = (lambda x, y : (x * y))
```

```
(f 3 4) ⇒ f(3,4)
```

```
boolean? ⇒ (lambda x : (type(x) == bool))
```

```
(L3
(define b (> 3 4))
(define x 5)
(define f (lambda (y) (+ x y)))
(define g (lambda (y) (* x y)))
(if (not b) (f 3) (g 4))
(if (= a b) (f 3) (g 4))
```

```

(if (> a b) (f 3) (g 4))
((lambda (x) (* x x)) 7)
)
⇒
b = (3 > 4)
x = 5
f = (lambda y : (x + y))
g = (lambda y : (x * y))
(f(3) if (not b) else g(4))
(f(3) if (a == b) else g(4))
(f(3) if (a > b) else g(4))
(lambda x : (x * x))(7)

```

The procedure gets an L2 AST and returns a string of the equivalent Python program.

To make things simpler, you can assume that the body of the lambda expressions contains one expression.

Note: The primitive operators of L2 are: +, -, *, /, <, >, =, number?, boolean?, eq?, and, or, not

Hint: Take a look at the unparse procedure.

The code should be submitted in file src/q4.ts

You can test your code with test/q4-tests.ts

Good Luck!