

## 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`, `L31-ast.ts`, `q3.ts`, `q4.ts` files in the correct places. 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 by the Design By Contract methodology.

Do not send assignment related questions by e-mail, use the forum instead.

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. In order to run the tests, run `npm test` from the command line.

**Important:** do not add any extra libraries in the supplied template files, otherwise, we will fail to compile and you will receive a grade of zero. If you find that we forgot to import necessary libraries, 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** 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]

**Q1.3** 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]

**Q1.4** In [practical session 5](#), we deal with two representations of primitive operations: *PrimOp* and *Closure*. List an advantage for each of the two methods [2 points].

**Q1.5** For the following high-order functions in L3, which gets a function and a list as parameters, 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** What is *lexical address*? Give an example which demonstrates this concept [2 points]

**Q1.7** Let us define L31 as the L3 language with the addition of 'cond' special form (as described in [practical session 4](#))

**Note:** The cond expression **must include at least one cond-clause**, and **must include an else-clause** (in contrast to the description in practical session 4)

Complete the concrete and abstract syntax of L31:

```

<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[]))
          | ( 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>* )
```

[4 points]

Answers should be submitted in file id1\_id2.pdf

## Question 2: Programing in L3 [35 points]

**Q2.1- In this part you can also use the procedures: empty?, length.**

a. Implement in L3 the following procedures:

*take* - gets a *list* and a number *pos* and returns a new list whose elements are the first *pos* elements of the *list*. If the *list* is shorter then *pos*- return the *list*.

*take-map* - gets a *list*, a function *func* and a number *pos* and returns a new list whose elements are the first *pos* elements mapped by *func*. If the *list* is shorter then *pos*- return the mapped *list*.

*take-filter* - gets a *list*, a predicate *pred* and a number *pos* and returns a new list whose elements are the first *pos* elements of the *list* that satisfy *pred*. If the number of elements satisfy the predicate is less then *pos*- return the filtered *list*.

Examples:

```
(take (list 1 2 3) 2) → '(1 2)
```

```
(take '() 2) → '()
```

```
(take-map (list 1 2 3) (lambda (x) (* x x)) 2) → '(1 4)
```

```
(take-map (list 1 2 3) (lambda (x) (* x x)) 4) → '(1 4 9)
```

```
(take-filter (list 1 2 3 4) (lambda (x) (> x 1)) 2) → '(2 3)
```

```
(take-filter (list 1 2 3) (lambda (x) (> x 3)) 2) → '()
```

b. Implement in L3 the following procedures:

*sub-size* - gets a *list* and a number *size* and returns a new list of all the sublists of *list* of length *size*.

*sub-size-map* - gets a *list*, a function *func* and a number *size* and returns a new list of all the sublists of *list* of length *size* that all their elements are mapped by *func*.

In both procedures, you can assume that  $size \leq (length\ list)$ . if the list is not empty you can assume  $1 \leq size$ .

Examples:

```
(sub-size '() 0) → '(() )
```

```
(sub-size (list 1 2 3) 3) → '((1 2 3))
```

```
(sub-size (list 1 2 3) 2) → '((1 2) (2 3))
```

```
(sub-size (list 1 2 3) 1) → '((1) (2) (3))
```

```
(sub-size-map '() (lambda (x) (+ x 1)) 0) → '(() )
```

```
(sub-size-map (list 1 2 3) (lambda (x) (+ x 1)) 3) → '((2 3 4))
```

```
(sub-size-map (list 1 2 3) (lambda (x) (+ x 1)) 2) → '((2 3) (3 4))
```

```
(sub-size-map (list 1 2 3) (lambda (x) (+ x 1)) 1) → '((2) (3) (4))
```

## Q2.2

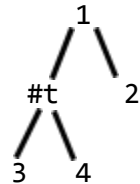
We can represent a binary tree in L3 using a list as follows: the first element in every nesting level represents the root of the sub-tree.

A leaf is represented by an atom (not a list/pair).

A missing child is represented as the empty list.

An empty tree is represented by an empty list.

For example:



Is represented as:

'(1 (#t 3 4) 2)

- a. Implement in L3 the following procedures:

root- gets a list representing a tree and returns the value of the root.

left- gets a list representing a tree and returns the subtree of the left son, or an empty list if there is no left son.

right- gets a list representing a tree and returns the subtree of the right son, or an empty list if there is no right son.

In all 3 procedures above, you can assume the tree is valid and contains the requested nodes.

In the following two sections, to enforce the principle of encapsulation, your implementation of count-node and mirror-tree should only use the functions root, left and right when accessing the tree parameter.

- b. Implement in L3 the procedure count-node which given a list representing a *tree* and an atomic *val*, returns the number of nodes whose value is equal to *val*.

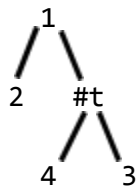
For example:

(count-node '(1 (#t 3 #t) 2) #t) → 2

(count-node '(1 (#t 3 #t) 2) 4) → 0

- c. Implement in L3 the procedure mirror-tree which given a list representing a *tree*, returns the mirrored tree.

For example, the mirrored tree for the example above will be:



Is represented as:

'(1 2 (#t 4 3))

### Q2.3

- a. Implement in L3 the following procedures to support result, ok and error structures:
- make-ok - gets a *value* and returns an ok structure for the *value* of type result.
  - make-error - gets an error *message* and returns an error structure for the *message* of type result.
  - ok? - type predicate for *ok*.
  - error? - type predicate for *error*.
  - result? - type predicate for *result*.
  - result->val - gets a *result* structure and returns the value it represents, or the error message for error. If the given result is not a result, return an error structure with the message "Error: not a result"

Examples:

```
(define ok (make-ok 1))  
(ok? ok) → #t  
(error? ok) → #f  
(result? ok) → #t  
(result->val ok) → 1
```

```
(define error (make-error "some error message"))  
(error? error) → #t  
(ok? error) → #f  
(result? error) → #t  
(result->val error) → "some error message"
```

```
(define not-ok 'ok)  
(ok? not-ok) → #f  
(error? not-ok) → #f  
(result? not-ok) → #f  
(result->val (result->val not-ok)) → "Error: not a result"
```

- b. Implement in L3 the procedure bind which given a function *func* from a non-result to result, returns a new function which given a result, returns the activation of *func* on its value or an error structure accordingly. If the given result is not a result, return an error structure.

For example:

```
(define inc-result (bind (lambda (x) (make-ok (+ x 1)))))
```

```
(define ok (make-ok 1))  
(result->val (inc-result ok)) → 2
```

```
(define error (make-error "some error message"))  
(result->val (inc-result error)) → "some error message"
```

**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 Transformations [20 points]**

- Implement the parser of L31, as defined in **Q1.7** above.
- Write the procedure *l31ToL3* which transforms a given L31 program to a L3 program.

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.

The procedure gets an L30 AST and returns a string of the equivalent 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)
```

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

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

The code should be submitted in file src/q4.ts  
You can test your code with test/q4-tests.ts

**Good Luck!** 😊