Examples for Programming Language Features

Ch 1 Preliminaries

1.3 Language Evaluation Criteria

1.3.3 Reliability

1.3.3.1 Type Checking

The following C program compiles and runs!

```
foo (float a) {
    printf (“a: %g and square(a): %g\n”, a, a*a);
}
main () {
    char z = ‘b’;
    foo(z);
}
```

Output is : `a: 98 and square(a): 9604`

Subscript range checking for arrays is a part of type checking, but it must be done in the **run-time**. Out-of-range subscript often cause errors that do not appear until long after actual violation.

```
#include <stdio.h>
foo (char s[])  {
    printf ("5th char in %s is %c\n", s, s[4]);
}

main () {
    char str[] = "abc";
    foo(str);
}
```

produces:

```
5th char in abc is }
```

Ch 3. Describing Syntax and Semantics

3.1. Formal Methods of Describing Syntax

Example: Python formal definition
(https://docs.python.org/3/reference/simple_stmts.html)

Ch 5. Names, Bindings, and Scopes

5.4.2.1 Static Type Binding

In Perl, $x is a scalar, @x is an array, %x is a hash.

```
$x = 5;
print $x ."\n";
$x = "Hello";
print $x ."\n";
@x = ("Ali", "Ayse", "Can", "Canan");
print "$x \n";
print "@x \n";
```

```
5
Hello
Hello
Ali Ayse Can Canan
```

```
%data = ('A', 4.0, 'A-', 3.7, 'B+', 3.3, 'B', 3);
print "$data{'A-'}\n";
```

```
3.7
```

5.4.2.2. Dynamic Type Binding

Javascript uses dynamic type binding.

```
list = [2, 4.33, 6, 8]; list is a single dimensioned array.
list = 73                    list is a simple integer.
```

5.4.3.1. Static Variables

Ex in C:

```
int a = 5; // global static variable
int foo(){
  static int b = 10; // static variable, scope is only the function.
}
```

5.4.3.3. Explicit Heap-Dynamic Variables

Ex in C++

```
  int *intnode;  // create a pointer
  intnode = new int; // create the heap-dynamic variable
  delete intnode;  // deallocate the heap-dynamic variable
```

Ex in Java:

```
Integer i = new Integer(5);
```

5.4.3.4 Implicit Heap-Dynamic Variables

Example in JavaScript:

```
numbers = [3, 5, 7, 15];
```

5.4-Summary

C Example:

```
int a1[10];                // static global variable.
static int a2 = 5;         // static global variable, initialized
void foo(){
  static int a3[10];       // static local array variable
  int a4[10];              // stack-dynamic variable
  int *a5 = (int *)malloc(10*sizeof(int));
                           // a5 (pointer) is stack-dynamic
                           // *a5 is explicit heap-dynamic
  ...
  free(a5);
}
```

5.5.6. Dynamic Scope

```
function big() {
    var x: integer;
    function sub1() {
    ... ?
    ... x ...
    }
    function sub2 () {
         var x: integer;
         ...
         sub1 ;
    }

    Sub2();
    sub1();
}
```

dynamic scoping (called form **big**)

Static scoping

dynamic scoping (called form **sub1**)

5.8 Named Constants

Java and C++ allow dynamic binding of values to named constants.

Example in Java

```
import java.util.Scanner;
public class A {
    public static void main(String[] args) {
      Scanner kb = new Scanner(System.in);
      int a = kb.nextInt();
      final int b = a * 2;
      System.out.println(a+" "+b);
    }
}
```

6. Data Types

6.3.3 String Length Options

- **Limited dynamic length strings:** (C and C++)

Following are equivalent in C

```
char c[] = "abcd";

char c[50] = "abcd";

char c[] = {'a', 'b', 'c', 'd', '\0'};

char c[5] = {'a', 'b', 'c', 'd', '\0'};
```

6.4 Enumeration Types

- Example in C:

```
/* enumeration type in C */
main () {
  enum day {mo, tu, we, th, fr, sa, su};
  enum day today;
  today = th;
  if ((today == sa) || (today == su))
        printf (“weekend\n”);
  else printf (“weekday\n”);
}
```

6.5.3 Subscript Bindings and Array Categories

Heap-dynamic array: Similar to stack-dynamic array, but the size can change during the lifetime.

Advantage: the array can grow and shrink.

Example:

ArrayList in Java, List in python, Arrays in perl (dynamic-array.pl)

Python

```
>>> mylist = [2, 1.6, (3+5j), 'c', "a word"]
>>> print mylist
[2, 1.6, (3+5j), 'c', 'a word']
>>> x = (1+2j) * mylist[2]
>>> x
(-7+11j)
```

6.6 Associative Arrays

Provided in Perl (called hash) and Java.

* Indexed by keys
* The size can grow and shrink dynamically.

```
#!/usr/local/bin/perl

%notlar = ("Ali" => 95, "Veli" => 80, "Selami" => 95);
```

To print an entry:

```
print "Veli’nin notu $notlar{Veli}\n";
```

To add a new entry:

```
$notlar{"Hulki"} = 75;
```

To delete an entry:

```
delete $notlar{"Veli"};
```

To change an entry:

```
$notlar{"Veli"} = 82;
```

To go through the array:

```
foreach $anahtar (keys %notlar) {
 print "$anahtar $notlar{$anahtar}\n";
}
```

To empty the array:

```
%notlar = ();
```

6.8. Tuple Types

A tuple is a data type that is similar to a record, except that the elements are not named.

Ex: Python

```
>>> myTuple = (3, 5.8, 'apple')
>>> myTuple[1]
5.8
```

```
>>> myTuple[1] = 6.7
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> myTuple = [3, 5.8, 'apple']   #Now, it is a list
>>> myTuple[1] = 6.7
>>> myTuple = (3, 5.8, 'apple')  # Back to tuple
>>> yourTuple = (1, 'pear')
>>> print myTuple + yourTuple
(3, 5.8, 'apple', 1, 'pear')
>>> print yourTuple
(1, 'pear')
>>> del yourTuple
>>> print yourTuple
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'yourTuple' is not defined
```

List Types

Lists were first supported in Lisp and Scheme.

Ex: Python:

```
>>> myList = [1, 2.3, "three"]
>>> del myList[1]
>>> myList
[1, 'three']
>>> myList.insert(1,"orange")
>>> myList
[1, 'orange', 'three']
>>> myList.append("plum")
>>> myList
[1, 'orange', 'three', 'plum']
```

6.10. Union Types

A **union type** may store different type values at different times in the same location.

Type checking must be dynamic.

Example in C:

```
#include <stdio.h>
#include <string.h>
```

```
union Data {
  int i;
  float f;
  char str[20];
};

int main() {
  union Data data;
  data.i = 10;
  data.f = 220.5;
  strcpy( data.str, "C Programming");
  printf( "data.i : %d\n", data.i);
  printf( "data.f : %f\n", data.f);
  printf( "data.str : %s\n", data.str);
  return 0;
}
```

Generates the following output:

```
data.i : 1917853763
data.f : 4122360580327794860452759994368.000000
data.str : C Programming
```

Size of a variable of union type:

```
#include <stdio.h>
#include <string.h>

union Data {
  int i;
  float f;
  char str[20];
};

int main( ) {
  union Data data;
  printf("Memory size occupied by data: %d\n", sizeof(data));
  return 0;
}
```

Prints 20.

6.11.3.2. Lost heap-dynamic variables

C++ Example

```
void foo(){
  int * x = new int;
}
foo(); // no way to reach the allocated integer: memory leakage
```

C++ Example

```
int * x = new int;
x = new int; // no way to reach the first allocated integer: memory leakage
```

9. Subprograms

9.2.3 Parameters

Python Example / positional parameter passing

```
def sum(x, y, z):
  return x + y + z
u = sum(a, b, c)
```

Python Example / positional with defaults

```
def sum(x, y, z=3):
  return x + y + z
u = sum(a, b)
u = sum(a, b, c)
```

Python Example / keyword based:

```
def sum(x, y, z=3):
  return x + y + z
u = sum(y=a, x=b)
u = sum(y=a, z=c, x=b)
```

Python Example / variable number of arguments:

```
def sum(x, y, *z):
  s = x + y
  for e in z:
    s = s + e
  return s
u = sum(a, b)
u = sum(a, b, c, 3, 5)
```

Python Example / variable number of arguments:

```
def sum(x, y, *z, **w):
  s = x + y
  for e in z:
    s = s + e
  for k,e in w.iteritems():
    s = s + e
  return s
u = sum(a, b)
u = sum(a, b, c, d, i=3, j=5)
```

Python Example / unpacking:

```
def sum(x, y, z, t):
  return x + y + z + t

v = [3, 5, 6, 8]
u = sum(*v) # same as sum(3, 5, 6, 8)
```

9.5.2 Parameter passing methods

The output of the program considering static scoping, sub-expression evaluation order of left-to-right, and:

- parameter passing with pass-by-value-result
- parameter passing with pass-by-reference
- parameter passing with pass-by-value

```
int y;
int z;
int foo(int x) {
  x = x + 5;
  y = x;
  x = x + 6;
  return y;
}

int bar(int x){
  y = foo(x) * x;
  return x;
}

void main(){
  y = 4;
  z = bar(y);
  print(y, z);
}
// Pass-by-value-result: 15 15
// Pass-by-reference: 225 225
// Pass-by-value: 36 4
```

9.5.2.5. Pass-by-name

Example in Scala

https://alvinalexander.com/source-code/scala/simple-scala-call-name-example

(Scala is a type-safe JVM language that incorporates both object oriented and functional programming)

9.6 Parameters That Are Subprograms

Python Example

```
def map(op, items):
  res = []
  for item in items:
    res.append(op(item))
  return res

def square(x):
  return x*x

def triple(x):
  return 3*x

print(map(square, [1, 2, 3])) # prints [1, 4, 9]
print(map(triple, [1, 2, 3])) # prints [3, 6, 9]
```

C++ Example

```
vector<int> map(int (*op)(int), vector<int> const & list){
  vector<int> res;
  for (int v: list){
    int mappedValue = (*op)(v);
    res.push_back(mappedValue);
  }
  return res;
}

int square(int x){
  return x*x;
}

int triple(int x){
  return 3*x;
}

vector<int> list = {1, 2, 3, 4};
vector<int> res = map(&square, list);
vector<int> res2 = map(&triple, list);
```

9.12. Closures

A JavaScript closure example:

http://dijkstra.cs.bilkent.edu.tr/~guvenir/closure.htm

Python Example:

```
def make_adder(x):
  def adder(y):
    return x+y # x is captured from y.
  return adder # make_adder returns inner function.

f = make_adder(3) # f is a function
print(f(5)) #prints 8
# 3 of the previous line is captured as x
```

C++ Example:

```
function<int(int)> make_adder(int x){
  auto adder = [=] (int y) {return x+y; };
  return adder;
}
auto adder = make_adder(3);
cout << adder(5);
```

9.13. Coroutines

Not exactly a full-coroutine implementation, but a similar feature in Python, "generators" example:

```
def genPairs(n):
  for i in range(0, n):
    for j in range(i+1, n):
      yield (i, j)

for p in genPairs(5):
  print(p)
```

10. Implementing Subprograms

10.2 Implementing "Simple" Subprograms

Example in Fortran

```
      INTEGER I,J
      COMMON I
      CALL X
      GOTO 10
   10 CONTINUE
      END

      SUBROUTINE X
      INTEGER K, J
      COMMON I
      K=5
      I=6
      J=I+K
      RETURN
      END
```

The translator performs the following bindings for the main program:

```
I ↔ d[COMMON, 0]
J ↔ d[MAIN,1]
10 ↔ c[MAIN,3]          CONTINUE statement
X ↔ c[X,0]              first statement of X
```

And the following bindings for the subroutine X:

```
I ↔ d[COMMON, 0]
K ↔ d[X, 1]
J ↔ d[X, 2]
```

The linker then performs a further binding of addresses by combining the main program and the subroutine X.

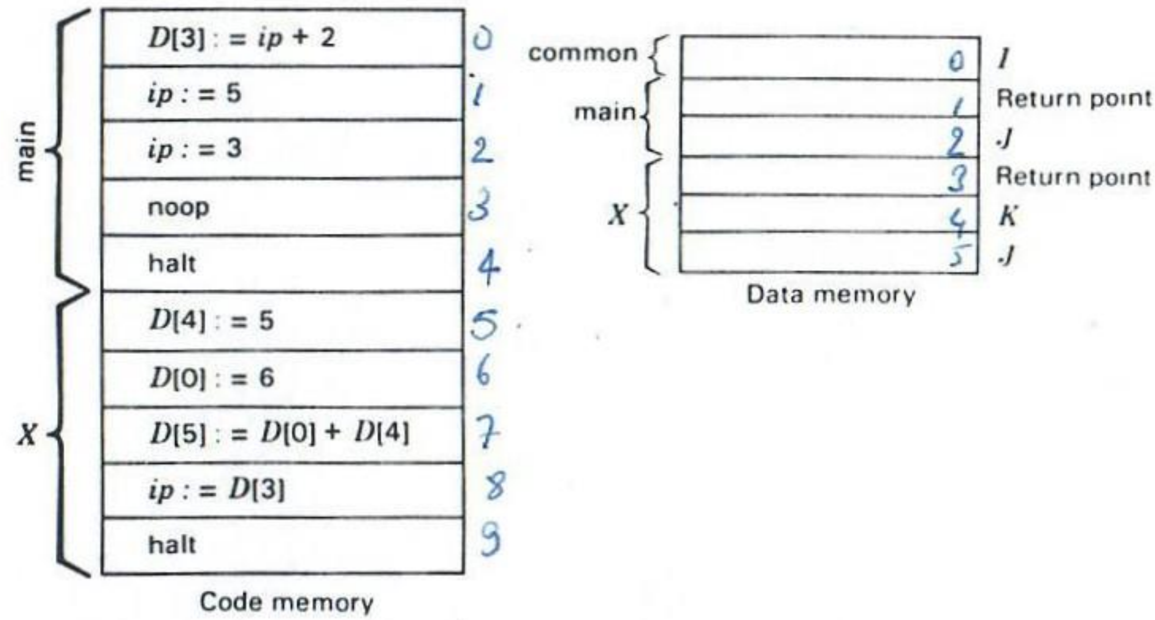
It produces the following bindings in the main program:

```
I ↔ D[0]
J ↔ D[2]
10 ↔ C[3]
X ↔ C[5]
```

And the following bindings for X:

```
I ↔ D[0]
K ↔ D[4]
J ↔ D[5]
```

The contents of the memory will be as follows:



The contents of the Data memory during the execution: