CS 536 Announcements for Wednesday, April 3, 2024

Last Time

- runtime environments
- runtime storage layout
- static vs stack allocation
- activation records
- what happens on function call, entry, return

Today

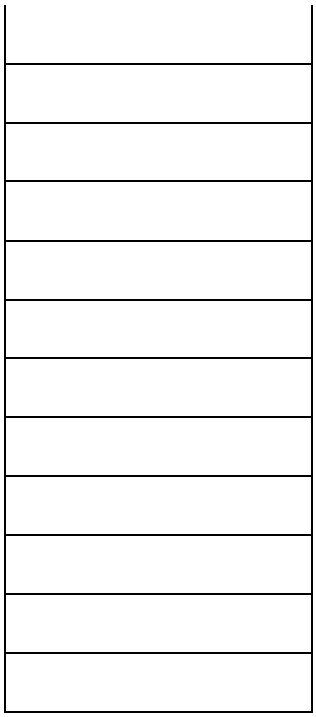
- parameter passing
- terminology
- different styles
  - what they mean
  - how they look on the stack
  - compare and contrast

Next Time

- runtime access to variables in different scopes

Example

```
#1  integer summation{integer max} [
#2    integer sum.
#3    integer k.
#4    sum = 0.
#5    k = 1.
#6    while k <= max [
#7      sum = sum + k.
#8      k++.
#9    ]
#10   return sum.
#11 ]
#12 void main{} [
#13   integer x.
#14   x = summation(4).
#15   write << x.
#16 ]
```



Parameter passing: terminology

R-value – value of an expression

L-value – value with with a location

pointer – a variable whose value is a memory address

aliasing – when two (or more) variables hold the same address

In **definition** of function/method/procedure

```
void f(int x, int y, bool b) { . . . }
```

In **call** to function/method/procedure

```
f(x + y, 7, true)
```

Types of parameter passing

pass by value

- when a procedure is called, the *values* of the actuals are copied into the formals

pass by reference

- when a procedure is called, the *address* of the actuals are copied into the formals

pass by value-result

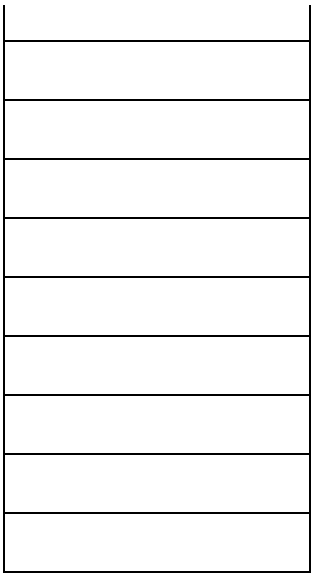
- when a procedure is called, the values of actuals are passed
- when procedure is ready to return, final values of formals are copied back to the actuals

pass by name

- (conceptually) each time a procedure is called, the body of the procedure (the callee) is rewritten with the actual text of the actual parameters
- like macros in C/C++, but conceptually the rewriting occurs at runtime

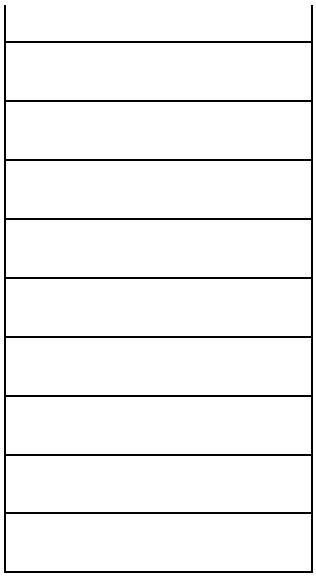
Example: pass by value

```
void f(int x, int y, int z) {
    x = 3;
    y = 4;
    z = y;
}

void main() {
    int a = 1, b = 2, c = 3;
    f(a, b, c);
    f(a+b, 7, 8);
}
```



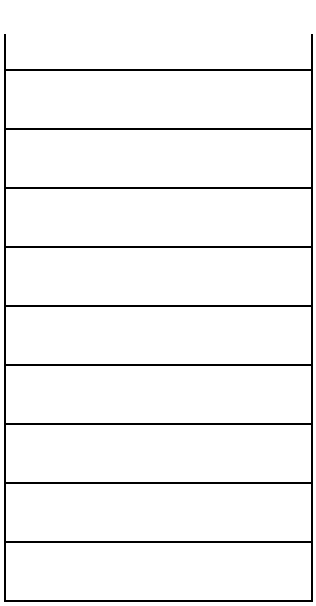
Example: pass by reference

```
void f(int x, int y, int z) {
    x = 3;
    y = 4;
    z = y;
}

void main() {
    int a = 1, b = 2, c = 3;
    f(a, b, c);
    f(a+b, 7, 8);
}
```



Example: pass by value-result

```
void f(int x, int y, int z) {
    x = 3;
    y = 4;
    z = y;
}

void main() {
    int a = 1, b = 2, c = 3;
    f(a, b, c);
    f(a+b, 7, 8);
}
```



Parameter passing example

```
class Point {
     Position p;
     ...
}
class Position {
     int x, y;
     ...
}
void doIt(Point pt, Position pos) {
    pos = pt.p;
    pos.x++;
    pos.y++;
}
void main() {
    Position loc;
    Point dot;
    // code to initialize Point dot with position (1, 2)
    // code to initialize Position loc at (3, 4)
    doIt(dot, loc);
}
```

In Java, `loc` & `dot` are *references* to objects (in the heap)

In C++, `loc` & `dot` *are* objects (in the AR of `main`)

Parameter passing example (cont.)

Pass by value in Java

Pass by value in C++

Pass by reference in C++

What are the (*x*,*y*) coordinates of `dot` and `loc` after the call to `doIt`?

	Pass by value (Java)	Pass by value (C++)	Pass by reference (C++)
`dot`			
`loc`			

Aliasing and parameter passing

How aliasing can happen

- via pointers (in pass by value) – aliasing of actuals and formals

```
doIt(dot, loc);  // in Java
```

- when a global variable is passed by reference

```
int t = 0;

void h(int x) {
    x = 7;
    t = 4;
}

void main() {
    h(t);
}
```

- when a parameter is passed by reference more than once

```
void f(int x, int y, int z) {
    x = 3;
    y = 4;
    z = y;
}

void main() {
    int a = 1, b = 2, c = 3;
    f(a, a, b);
}
```

What happens in pass by value-result?

Code generation and parameter passing

Efficiency considerations (calls, accesses by callee, return)

Pass by value

- copy values into callee's AR
- callee directly accesses AR locations

Pass by reference

- copy addresses into callee's AR
- access in callee via indirection

Pass by value-result

Handling objects

```
class Point {                    class Position {
    Position p;                      int x, y;
    ...                              ...
}                                }

void doIt(Point pt, Position pos) {
    pos = pt.p;
    pos.x++;
    pos.y++;
}

void main() {
    Position loc;
    Point dot;
    // ... initialize dot with position (1, 2)
    // ... initialize loc at (3, 4)
    doIt(dot, loc);
}
```

In Java, `loc` and `dot` hold the addresses of objects

In C++, `loc` and `dot` are objects in the stack

Compare and contrast

Pass by value

- no aliasing
- easier for static analysis
- called function (callee) is faster

Pass by reference

- more efficient when passing large objects
- can modify actuals

Pass by value-result

- more efficient than pass by refence for small objects
- if no aliasing, can be implemented as pass by reference for large objects