Lecture 3: References, Recursion, and Lists

8/31/2020

Primitive Types

Variables in Java

```
Walrus a = new Walrus(1000, 8.3);
Walrus b;
b = a;
b.weight = 5;
System.out.println(a);
System.out.println(b);

Result:
5
5
```

- The change to b will affect a

```
int x = 5;
int y;
y = x;
x = 2;
System.out.println(x);
System.out.println(y);

Result:
2
5
```

- The change to x will not affect y

Bits

- Your computer stores information in "memory"
  - Information is stored in memory as a sequence of ones and zeros
    - Example: 72 stored as 01001000
    - Example: Letter H stored as 01001000 (same as the number 72)
    - Example: True stored as 00000001
- Each Java type has a different way to interpret the bits:
  - 8 primitive types in Java:
    - byte
    - short

- int
- long
- float
- double
- boolean
- char

Declaring a Variable (simplified)

```
int x;
double y;
x = -1431195969;
y = 567213.112
```

- When you declare a variable of a certain type in Java:
    - Your computer sets aside exactly enough bits to hold a thing of that type
        - Ex: Declaring an int sets aside a "box" of 32 bits
        - Ex: Declaring a double sets aside a box of 64 bits
    - Java creates an internal table that maps each variable name to a location
    - Java does NOT write anything into the reserved boxes
        - For safety, Java will not let access a variable that is uninitialized

Simplified Box Notation

- We'll use simplified box notation
    - Instead of writing memory box contents in binary, we'll write them in human readable code

The Golden Rule of Equals (GRoE)

- Given variables y and x:
    - `y = x` **copies** all the bits from x into y

Reference Types

Reference Types

- There are 8 primitive types in Java
- Everything else, including arrays, is a **reference type**

Class Instantiations

- When we instantiate an Object
    - Java first allocates a box of bits for each instance variable of the class and fills them with a default value (e.g. 0, null)
    - The constructor then usually fills every box with some other value

```
public class Walrus {
    public int weight;
    public double tuskSize;

    public Walrus(int w, double ts) {
        weight = w;
        tuskSize = ts;
    }
}
```

- Can think of new as returning the address of the newly created object
    - Addresses in Java are 64 bits
    - Example: If object is created in memory location 111111111, then new returns 1111111111

Reference Type Variable Declarations

- When we declare a variable of any reference type:
    - Java allocates exactly a box of size 64 bits, no matter what type of object
    - These bits can be either set to:
        - Null (all zeros)

          ```
          Walrus someWalrus;
          someWalrus = null;
          ```

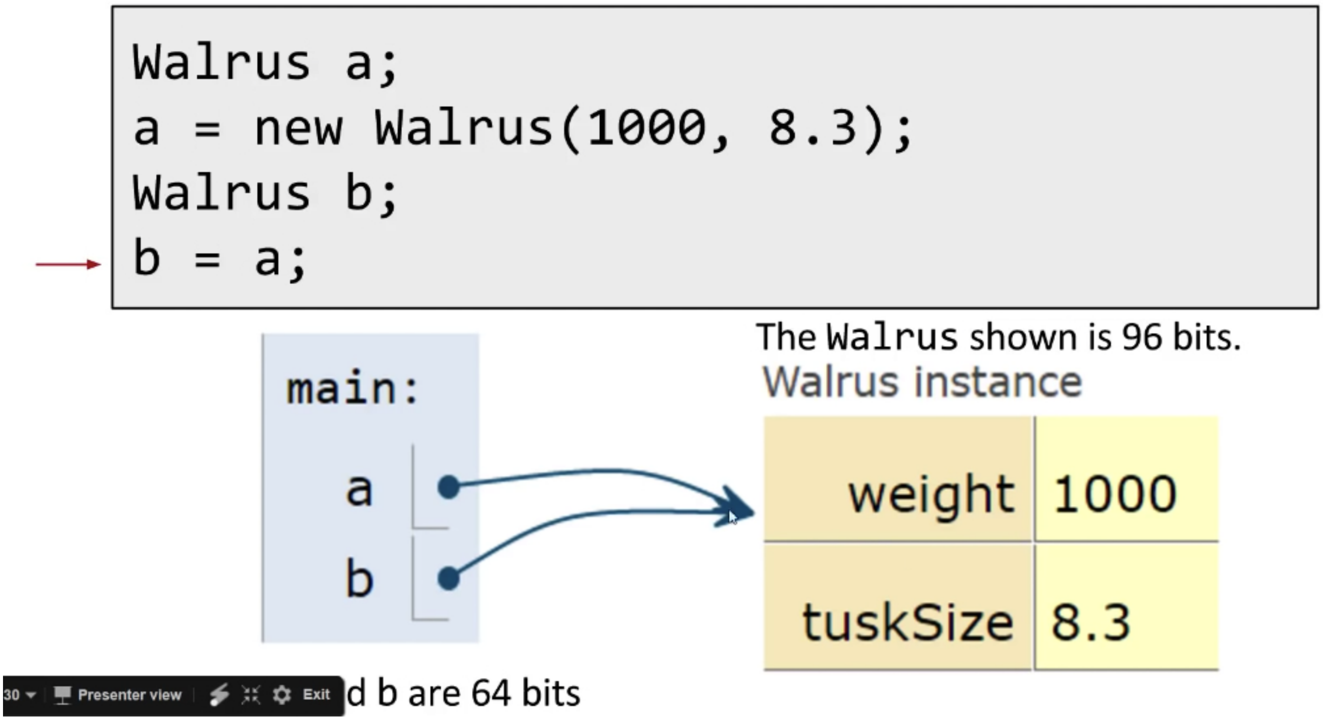
        - The 64 bit "address" of a specific instance of that class (returned by new)

          ```
          Walrus someWalrus;
          someWalrus = new Walrus(1000, 8.3);
          ```

- The 64 bit addresses are meaningless to us as humans, so we'll represent:
    - All zero addresses with "null"
    - Non-zero addresses as arrows
    - Basically, the box-and-pointer notation from CS 61A

Reference Types Obey the Golden Rule of Equals

- Just as with primitive types, the equals sign copies the bits
    - In terms of our visual metaphor, we "copy" the arrow by making the arrow in the b box point at the same instance as a
        - a and b are 64 bits



```
Walrus a;
a = new Walrus(1000, 8.3);
Walrus b;
b = a;
```

The Walrus shown is 96 bits.

d b are 64 bits

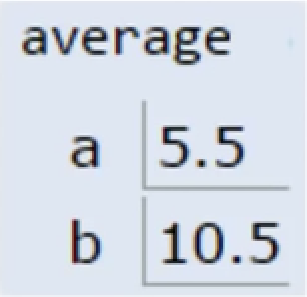
Parameter Passing

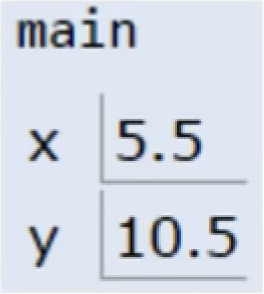
The Golden Rule of Equals (and Parameter Passing)

- Given variables b and a:
  - `b = a` copies all the bits from a into b
- Passing parameters obeys the same rule: Simply **copy the bits** to the new scope (parameters are "passed by value")

```
public static double average(doubl a, double b) {
    return (a + b) / 2;
}

public static void main(String[] args) {
    double x = 5.5;
    double y = 10.5;
    double avg = average(x, y);
}
```





The Golden Rule: Summary

- There are - types of variables in Java:
  - 8 primitive types
  - The 9th type is references to Objects (an arrow). References may be null
- In box-and-pointer notation, each variable is drawn as a labeled box and values are shown in the box
  - Addresses are represented by arrows to object instances
- The golden rule:
  - `b = a` **copies the bits** from a into b
  - Passing parameters **copies the bits**

Instantiation of Arrays

Declaration and Instantiation of Arrays

- Arrays are also Objects. As we've seen, objects are instantiated using the `new` keyword
  - `int[] x = new int[]{0, 1, 2, 95, 4};`
- `int[] a;`: Declaration
  - Declaration creates a 64 bit box intended only for storing a reference to an int array. **No object is instantiated**
- `new int[]{0, 1, 2, 95, 4};`: Instantiation
  - Instantiates a new Object, in this case an int array
  - Object is anonymous!

Assignment of Arrays

- `int[] x = new int[]{0, 1, 2, 95, 4};`
  - Creates a 64 bit box for storing an int array address
  - Creates a new Object, in this case an int array (Instantiation)

    - Puts the address of this new Object into the 64 bit box named a (assignment)
- Note: Instantiated objects can be lost!
    - If we were to reassign a to something else, we'd never be able to get the original Object back!

IntList and Linked Data Structures

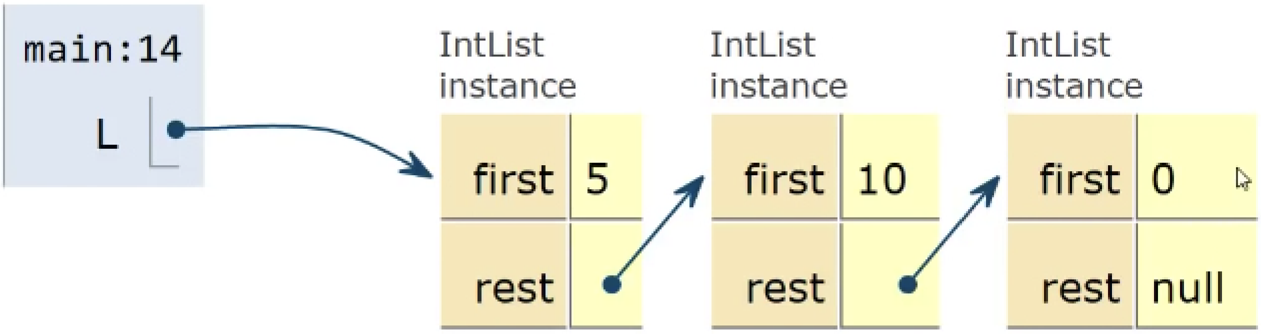
IntList

- Let's define an InstList as an object containing two member variables:
    - `int first;`
    - `IntList rest;`

```
public class IntList {
    public int first;
    public IntList rest;

    public IntList(int f, IntList r) {
        first = f;
        rest = r;
    }

    public static void main(String[] args) {
        IntList L = new IntList(15, null);
        L = new IntList(10, L);
        L = new IntList(5, L);
    }
}
```



IntList

- And define two versions of the same method:
    - `size()`
    - `iterativeSize()`

```
public class IntList {
    public int first;
    public IntList rest;
    public IntList(int f, IntList r) {
        first = f;
        rest = r;
    }

    public int size() {
        // Return the size of the list using... recursion!
        if (rest == null) {
            return 1;
        }
        return 1 + this.rest.size();
    }

    public int iterativeSize() {
        // Return the size of the list using no recursion
        IntList p = this;
        int totalSize = 0;
        while (p != null) {
            totalSize += 1;
            p = p.rest;
        }
        return totalSize;
    }

    public static void main(String[] args) {
        IntList L = new IntList(15, null);
        L = new IntList(10, L);
        L = new IntList(5, L);
    }
}
```

Challenge

- Write a method `int get(int i)` that returns the ith item in the list
  - Assume the item exists
  - Front item is the 0th item

```
public class IntList {
    public int first;
    public IntList rest;

    public IntList(int f, IntList r) {
        first = f;
        rest = r;
    }

    public int size() {
        // Return the size of the list using... recursion!
        if (rest == null) {
            return 1;
        }
        return 1 + this.rest.size();
    }

    public int iterativeSize() {
        // Return the size of the list using no recursion
        IntList p = this;
        int totalSize = 0;
        while (p != null) {
            totalSize += 1;
            p = p.rest;
        }
        return totalSize;
    }

    public int get(int i) {
        // Returns the ith item of this IntList
        if (i == 0) {
            return first;
        }
        return rest.get(i - 1);
    }

    public static void main(String[] args) {
        IntList L = new IntList(15, null);
        L = new IntList(10, L);
        L = new IntList(5, L);
    }
}
```