From arrangements: non-objective objects
http://www.richardbeenen.com/id3.html

Implementing Objects

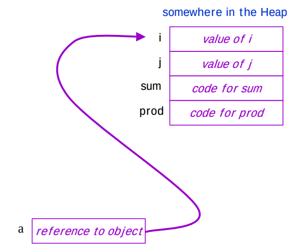
Lecture 10
CS 212 – Fall 2007

Intuitive View of an Object

```
class A {
   int i, j;

   A (int ii, int jj) {
            i = ii; j = jj;
            }
   int sum () {
            return i + j;
            }
   int prod () {
            return i * j;
            }
   }

a = new A(4, 8);
```



This is close to what's actually done except we don't really store the code with the object

Variables within Classes

- Local variables (i.e., local to a method) reside on the stack, just as before
  - Location is *FBR+offset*
- Instance variables (i.e., fields) are stored within the object
  - Location is *objectAddress+offset*

- Code for getting the value of a field

```
PUSHOFF fbrOffsetOfObjectRef  // Push address of object
PUSHIMM offsetOfField         // Push field's offset
ADD                           // Absolute address of field
PUSHIND                       // Push value stored at that address
```

- Code for setting the value of a field

```
PUSHOFF fbrOffsetOfObjectRef  // Push address of object
PUSHIMM offsetOfField         // Push field's offset
ADD                           // Absolute address of field
PUSHIMM valueToStore          // Value to place into field
STOREIND                      // Store value into address
```

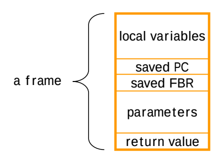
Calling a Method

- Basically, a method is just a function
  - Build a standard stack frame
  - Include one extra parameter: the object
- In other words, if the code is

      a.sum()

  then the extra parameter is a

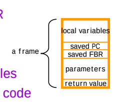
  (Actually, the address of a)



Function Call vs. Method Call

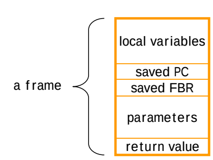
- Caller:
  - Push space for ret value
  - Push arguments
  - Push/update FBR
  - Push/update PC
- Callee:
  - Push local variables
  - Execute callee code
  - Clear local variables
  - Pop/restore PC
- Caller:
  - Pop/restore FBR
  - Clear arguments
  - (Ret value is left on stack)

- Caller:
  - Push space for ret value
  - Push object's address
  - Push arguments
  - Push/update FBR
  - Push/update PC
- Callee:
  - Push local variables
  - Execute method code
  - Clear local variables
  - Pop/restore PC
- Caller:
  - Pop/restore FBR
  - Clear arguments
  - Clear object's address
  - (Ret value is left on stack)



Calling a Constructor

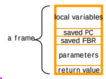
- Goal: On return, address of new object should be on top of stack
  - In Bali, we have the extra goal that the constructor should be useable as regular function
- Basically, a constructor is just a function
  - Build a standard stack frame
  - Called as a constructor
    - The return value is the new object—it is created when the constructor is called
  - Called as a function
    - The return value is the extra method-parameter



Function Call vs. Constructor Call

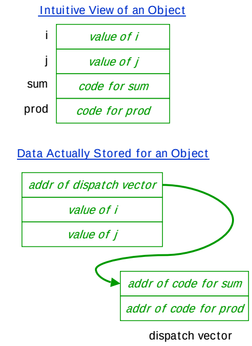
- Caller:
  - Push space for ret value
  - Push arguments
  - Push/update FBR
  - Push/update PC
- Callee:
  - Push local variables
  - Execute callee code
  - Clear local variables
  - Pop/restore PC
- Caller:
  - Pop/restore FBR
  - Clear arguments
  - (Ret value is left on stack)

- Caller:
  - Push/create object (need size)
  - Push arguments
  - Push/update FBR
  - Push/update PC
- Callee:
  - Push local variables
  - Execute constructor code
  - Clear local variables
  - Pop/restore PC
- Caller:
  - Pop/restore FBR
  - Clear arguments
  - (Ret value is left on stack)



Dispatch Vector

- For a method, we don't store a copy of the method's code with each class instance
  - Instead we can store the address of the method's code
- But each instance of a class refers to exactly the same set of methods
  - It's wasteful for each object to store an address for each of its methods
- Instead, we use a *dispatch vector*
  - A simple table of method addresses stored somewhere else in the Heap

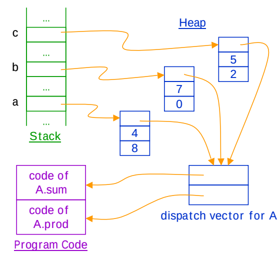


Shared Data for a Class

- Instances of the same class share the same *dispatch vector*
- This implies that your sam-code must create a *dispatch vector* for *each class*

- If there are static variables (i.e., class variables)
  - These would be stored in a *Static Data Area* with the dispatch vector
  - There would be one such *Static Data Area* for each class
  - We don't have static variables in Bali

a = new A(4, 8);
b = new A(7, 0);
c = new A(5, 2);



What Info is Needed to Generate Code?

- For a local variable
  - Offset from FBR
- For a field
  - Address of object
  - Offset of field from start of object
- For a method
  - Address of object
    - From this, you can derive address of dispatch vector
  - Offset of method from start of dispatch vector

- All of this offset information is stored in the Symbol Table(s) (along with other information)

- For a field or a method
  - Address of object comes from local variable
    - Examples: a.i or a.sum()
  - Or address of object comes from hidden "this" parameter of a method
    - Examples: i or sum() when used within a method of A

Multiple Symbol Tables

- Program Symbol Table
  - Global variables
    - Type and location
  - Classes
    - Where to find class's dispatch vector
    - Size of corresponding object
  - Functions & constructors
    - Where to find corresponding code
    - Parameter types and return type
  - Need to know the above function and constructor information *before* generating any function or constructor code
    - Can use separate pass over the AST

- Class Symbol Table
  - Fields
    - Type & offset within object
  - Methods
    - Param types & return type
    - Offset within dispatch vector
  - *Private* fields and methods can be removed from table after class has been compiled
    - Note: all Bali fields and methods are *public*

- Method/Function Symbol Table
  - Local variables
    - Type and offset from FBR
  - Entire table can be deleted after compiling the method or function

Inheritance

- We aren't doing inheritance for Bali Part 4, but here's how it works

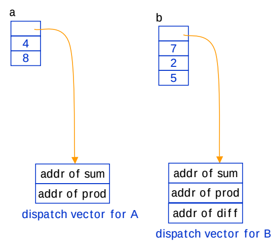
- An object inherits all *public* fields and methods of its superclass
  - But the *private* fields and methods still exist
- When we create the code for a method, we don't know if we are using
  - An instance of the class itself
  - Or an instance of some subclass

- This implies that a subclass had better use the same offsets as its superclass
  - Same dispatch vector (with any new stuff at the end)
  - Same object layout (with any new stuff at the end)
- This allows a method's code to still work even though it's dealing with a subclass
  - Any "new stuff at the end" is never accessed by the method

Inheritance Example

```
class A {
   int i, j;
   A (int ii, int jj) {
        i = ii; j = jj;
        }
   int sum () {
        return i + j;
        }
   int prod () {
        return i * j;
        }
}
class B extends A {
   int k;
   B (int ii, int jj) {
        super(ii, jj);
        k = i – j;
        }
   int diff () {
        return k;
        }
   }
```

```
a = new A(4, 8);
b = new B(7, 2);
x = b.prod();          // Uses A's code
```



Overriding vs. Shadowing

- In Java, what happens if a subclass redefines fields or methods that exist in the superclass?
- A method with the same signature will *override* the superclass's method
  - In other words, an instance of the subclass should call the *new method*, not the old one
  - This is done by altering the dispatch vector
    - In the subclass's dispatch vector, the address of the new code *replaces* the address of the old code
- A field with the same name will *shadow* the superclass's field
  - In other words, the variable accessed depends on where the code is
  - This is done by appending the new field on the end of the object layout (just as if the name were completely new)
    - The Symbol Table for the subclass knows only about the new field

Multiple Inheritance

- Java (and extended-Bali) allow a class to inherit from at most one other class
- Other languages allow multiple inheritance
  - It becomes difficult to make offsets match for both the object layout and the dispatch vector
  - Other schemes are used