Ur-Java

Ur-Java

- Let us introduce Java in two stages:
  - Ur-Java: a class language, no objects
  - Java: a language with objects
- Ur-Java is a subset of Java
  - every Ur-Java program is a Java program
- Why study Ur-Java?
  - I want you to have a mental model of how Java programs are executed
  - Ur-Java has a simple execution model

Two aspects of Ur-Java

- Statics: what does the program look like?
  - What are the constructs in the language?
- Dynamics: what happens when you run the program?
  - What is the correspondence between names and storage locations?
  - What is the sequence in which program operations are executed?

Statics of Ur-Java

Example of Ur-Java program

```
class Top{
    public static void main(String[] args) {
            Work.squares(1,10);
             System.out.println(Work.powCalls);
              }
}
class Work{
    public static int powCalls = 0;

    public static void squares(int lo, int hi){
        for (int i = lo; i < hi; i++)
            System.out.println(pow(i,2));
    }
    public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
}
```

class variable of type int

class method of type int x int → void

class method of type int x int → int

Ur-Java program

- Collection of classes
  - Example: Top and Work are two classes
- Class: like a folder that contains
  - some class variables (maybe none)
  - some class methods (maybe none)
  - these are called class members.
  - Just as in folder, class should contain logically related members.
    - Example: members in Java class Math
      - Class variables named PI, E etc.
      - Class methods named sin,cos,pow,….

Names of members

How does a method in one class refer to a member of another class?

- Complete path name: className.memberName
  - (eg) Top.main, Work.powCalls,Work.squares
- Relative path name: memberName only
  - Used when referring to member in same class as method
  - (eg) method Work.squares can refer to member Work.powCalls simply as powCalls
- Analogy: long-distance call vs local call in phone system

Binding time

- Binding: association between name and class member
  - (eg) System.out.println(pow(i,2));
  - pow is name for some class member. Which one is it?
- Ur-Java: static binding
  - Association between name and member can be determined from text of program without running the program
  - (eg.) pow means the method defined in Work.pow
  - "static" means compiler can determine binding
- Contrast: dynamic binding – association between name and member can only be determined by running program
  - See later when we look at object-oriented Java

Visibility

- Class member M can be declared to be
  - *public*: visible to methods in other classes
  - *private*: visible only to methods in same class as M

Method overloading

- Can two methods in a class have the same name?
- Two methods in a class can have the same name provided
  - they take different numbers of arguments, or
  - the type of at least one argument is different
- This is called method overloading.
- Why is this useful?

- Suppose we want to define a power method for floats.
- Type of method for integers:
  - int x int → int
- Type of desired method for floats:
  - float x int → float
- We need another method – what should we name it?

Method overloading

```
public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }

public static float pow(float b, int p){
        powCalls = powCalls + 1;
        float value = 1.0;
        for (int i = 0;i <p; i++)
            value=value*b;
        return value;
    }
```

Finds powers of integers

Methods have same name but types of parameters are different.

Finds powers of floats

Why overloading

- We could of course have called the two methods iPow (powers of integers) and fPow (powers of floats).
- This obscures the similarity in their functionality: overloading method name is cleaner.
- How does compiler figure out which method to call when it sees invocation pow(….,…)?
  - In this example, type of first parameter tells it which method was intended to be invoked.

Variables in methods

```
public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
```

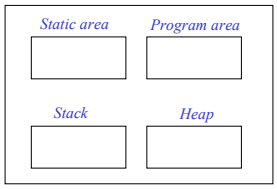
- Two kinds of variables:
  - Parameters: b,p
  - Local variables: value,i
- Variables not visible outside method
- Method parameters and local variables should not be declared to be public/private
  - by definition, they are visible only in that method

Editorial note

- Much of the power (and conceptual complexity) in OO-languages comes from the subtleties of determining the association between names and "things".
- In older languages like FORTRAN, a name stood for exactly one thing.
- On OO-languages, a name may mean different things at different places in program or at different times in program execution.
  - Method overloading is a simple example of this.
  - Method overriding is a more complex and powerful example (see later in inheritance).

Dynamics of Ur-Java

Memory map for modern languages



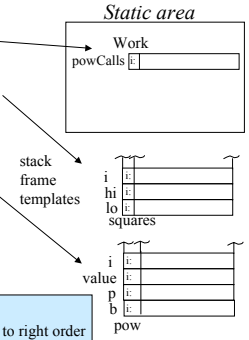
- Program area: code (like our SaM code)
  - Each method is compiled to SaM-like code by compiler
  - When program runs, this code is loaded into program area
- Static area: class variables
- Stack: frames containing method parameters/local variables
- Heap: objects created by constructor invocation
- Ur-Java: no objects, so no heap

Memory map

- Class variables
  - Created in static area when program execution begins
  - Stay in existence till program terminates
- Method parameters/local variables
  - Stack frame containing parameters/local variables created in stack area when method is invoked
  - Stack frame contains other information: ignore for now
  - Stack frame destroyed when method returns
- Note difference between these two
  - Each class variable corresponds to exactly one memory location for entire duration of program.
  - Method parameters/variables can correspond to different locations at different points in program execution.

Example:class Work

```
class Work{
    public static int powCalls = 0;

    public static void squares(int lo, int hi){
        for (int i = lo; i < hi; i++)
            System.out.println(pow(i,2));
    }
    public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
}
```



Stack frame: from bottom to top
- One slot per parameter, left to right order
- One slot per local variable

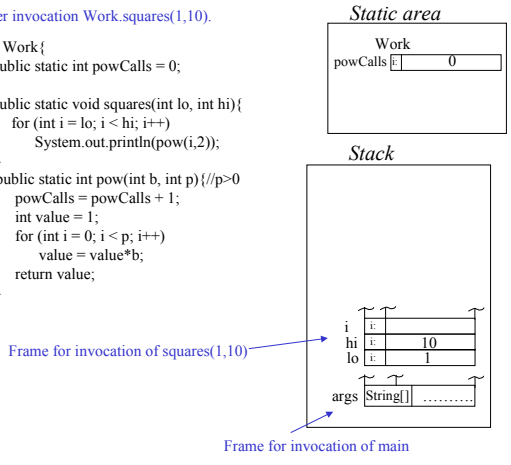
Example of Ur-Java program

```
class Top{
    public static void main(String[] args) {
        Work.squares(1,10);
        System.out.println(Work.powCalls);
    }
}
class Work{
    public static int powCalls = 0;

    public static void squares(int lo, int hi){
        for (int i = lo; i < hi; i++)
            System.out.println(pow(i,2));
    }
    public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
}
```

Let us look at stack after invocation squares(1,10).

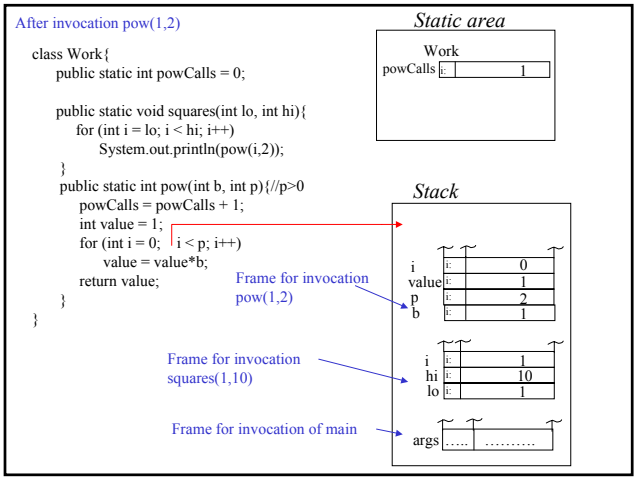
Just after invocation Work.squares(1,10).

```
class Work{
    public static int powCalls = 0;

    public static void squares(int lo, int hi){
        for (int i = lo; i < hi; i++)
            System.out.println(pow(i,2));
    }
    public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
}
```



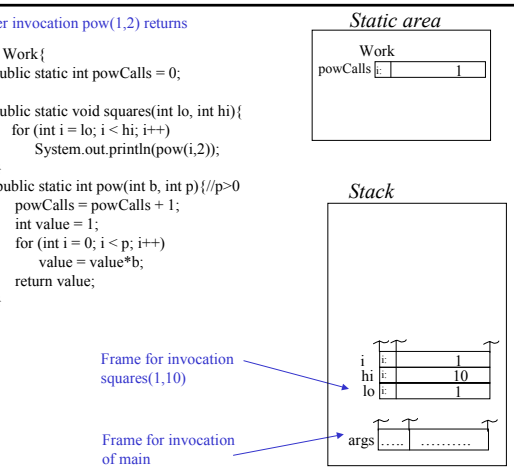
After invocation pow(1,2)

```
class Work{
    public static int powCalls = 0;

    public static void squares(int lo, int hi){
        for (int i = lo; i < hi; i++)
            System.out.println(pow(i,2));
    }
    public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
}
```



Just after invocation pow(1,2) returns

```
class Work{
    public static int powCalls = 0;

    public static void squares(int lo, int hi){
        for (int i = lo; i < hi; i++)
            System.out.println(pow(i,2));
    }
    public static int pow(int b, int p){//p>0
        powCalls = powCalls + 1;
        int value = 1;
        for (int i = 0; i < p; i++)
            value = value*b;
        return value;
    }
}
```



Why class variables?

- Constants needed by many methods/classes
  - PI,E in class Math
- Data that must survive method invocations
  - powCalls is one example
  - Another example: random number generation

Random number generation

- The following formula can be used to generate a sequence of random numbers

  $x_0 = 19$

  $x_k = (106 * x_{k-1} + 1283) \bmod 6075$

```
class Random {//returns sequence starting at x1
    private static int current = 19;
    public static float rand() {
        current = (106*current + 1283) % 6075;
        //return float in range [0,1]
        float scaled = current/6074;
        return scaled;
}
```

Note

- Use of class variable *current* is essential because value returned by an invocation of method `rand` depends on values computed by previous invocation of `rand`.
- Method parameters/variables are not adequate for this purpose.

Java note

- Java Math class has a random number generator
  - Math.random() : returns a random double value in range [0.0, 1.0)
  - Example: simulating a die [1..6]

```
public static int die() {
  return (int)(Math.floor(Math.random() * 6) + 1);
}
```

Final comments

- Ur-Java has classes, but no objects.
- Visibility of class members can be controlled with access specifiers such as *public* and *private*.
- Ur-Java is a conventional non-OO language like C except that visibility of class members can be controlled.

Additional material

Program Debugging

- Program development:
  - Edit/compile/run
  - When do you catch mistakes?
  - Prefer to do it as early as possible in development cycle
  - To understand this, let us look at categories of mistakes

Categories of mistakes

- Similar to categories in English
- Syntactic mistakes: "Spot give lecture."
  - Grammatical: "Spot gives a lecture."
- Semantic mistakes:
  - Type error: if Spot is a name only for dogs, sentence is syntactically correct, but meaningless
    - Do not need to know which dog Spot is
  - Runtime error: "John gives a lecture."
    - May or may not make sense depending on who John is
      - If John is 3 years old, does not make sense

PL examples

- Syntactic errors:
  - (eg) 3var = 5;
    //Java identifiers cannot start with digit
- Semantic errors:
  - Type errors:
    - (eg) a/b //if type of "a" is boolean
  - Runtime errors:
    - (eg) a/b //if value of b is 0

Program Debugging

- When do you catch mistakes?
  - Edit time: some syntactic errors
  - Compile time: type errors, missing method definitions,..
  - Run time: divide by zero errors,…
- Prefer to catch mistakes as early as possible in development cycle