Java Memory Management
Memory Allocation in Java

• When a program is being executed, separate areas of memory are allocated for each
  • class and interface
  • object
  • running method
Memory Areas in Java

• **Call stack / runtime stack / execution stack**
  • Used to store *method* information needed *while the method is being executed*, like
    • Local variables
    • Formal parameters
    • Return value
    • Where method should return to

• **Heap**
  • Used for
    • *Static* information (interfaces and classes)
    • *Instance* information (objects)
Memory allocated to your program

execution stack

objects in the heap

static space in the heap

Memory allocated to your program

execution stack

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static space in the heap
Memory Allocation in Java

• **Example**: What happens when an object is created by `new`, as in `Person friend = new Person(...);`

  • The reference variable has memory allocated to it on the *execution stack*
  • The object is created using memory in the *heap*
Runtime Stack

- **Execution stack (runtime stack)** is the memory space used for *method* information *while a method is being run*

- When a method is invoked, an *activation record* (or *call frame*) for that method is created and “pushed” onto the execution stack
  - All the information needed during the execution of the method is grouped together in the activation record
Call Frame or Activation Record for a Method

- Return value
- Local variables
- Formal Parameters
- Return address
Call Frame or Activation Record

• An activation record contains:
  • Address to return to after method ends
  • Method’s formal parameter variables
  • Method’s local variables
  • Return value (if any)

• Note that the values in an activation record are accessible only while the corresponding method is being executed!
public class CallStackDemo
{
    public static void m2()
    {
        System.out.println("Starting m2");
        System.out.println("m2 calling m3");
        m3();
        System.out.println("m2 calling m4");
        m4();
        System.out.println("Leaving m2");
        return;
    }
    public static void m3()
    {
        System.out.println("Starting m3");
        System.out.println("Leaving m3");
        return;
    }
}
public static void m4()
{
    System.out.println("Starting m4");
    System.out.println("Leaving m4");
    return;
}

public static void main(String args[])
{
    System.out.println("Starting main");
    System.out.println("main calling m2");
    m2();
    System.out.println("Leaving main");
}
Execution Stack for a Typical Calling Sequence

Frame for main
Frame for m2
main calls m2
Frame for m2
Frame for m3
m2 calls m3
Frame for m2
Frame for main
Return from m3
Frame for main
Frame for m4
m2 calls m4
Frame for m2
Frame for main
Return from m4

etc.
Execution Stack for a Typical Calling Sequence

- When the **main** method is invoked:
  - An activation record for **main** is created and pushed onto the execution stack
- When **main** calls the method **m2**:
  - An activation record for **m2** is created and pushed onto the execution stack
- When **m2** calls **m3**:
  - An activation record for **m3** is created and pushed onto the execution stack
- When **m3** terminates, its activation record is popped off and control returns to **m2**
Execution Stack for a Typical Calling Sequence

- When m2 now calls m4:
  - What happens next?
  - What happens when m4 terminates?

- What happens when m2 terminates?

- What happens when main terminates? Its activation record is popped off and control returns to the operating system.
Activation Records

• We will now look at some examples of what is in an activation record for a method
  • First for simple variables
  • Then for reference variables
Example: Activation Records - Simple Variables

```java
public class CallFrameDemo1 {
    public static double square(double n) {
        double temp;
        temp = n * n;
        return temp;
    }

    public static void main(String args[]) {
        double x = 4.5;
        double y;
        y = square(x);
        System.out.println("Square of " + x + " is " + y);
    }
}
```
Draw a picture of the activation records on the execution stack:

• What will be in the activation record for the **main** method?
  • Address to return to in operating system
  • Variable **args**
  • Variable **x**
  • Variable **y**

• What will be in the activation record for the method **square**?
  • Address to return to in main
  • Variable **n**
  • Variable **temp**
  • Return value
Discussion

• There will be an activation record on the execution stack for each method called. So what other activation record(s) will be pushed onto the execution stack for our example?
• Which activation records will be on the execution stack at the same time?
Heap Space

• **Static space**: contains *one* copy of each class and interface named in the program
  • Also contains static variables and static methods

• **Object space**:
  • Information is stored about *each* object:
    • Values of its instance variables
    • Type of object (i.e. name of class)
Object Creation

• Now let's look at reference variables …
• Memory is allocated in the heap area when an object is created using new
  • The reference variable is put in the activation record on the execution stack
  • The object is created using memory in the heap
public class CallFrameDemo2 {

    private static void printAll(String s1, String s2, String s3){
        System.out.println(s1.toString());
        System.out.println(s2.toString());
        System.out.println(s3.toString());
    }

    public static void main(String args[ ]){
        String str1, str2, str3;

        str1 = new String(" string 1 ");
        str2 = new String(" string 2 ");
        str3 = new String(" string 3 ");

        printAll(str1, str2, str3);
    }
}
Activation Records– Example 2

Draw a picture of the execution stack and of the heap as the program executes

- What will be the sequence of activation records on the execution stack?

for main
  for String constructor for str1 – then popped off
  for String constructor for str2 – then popped off
  for String constructor for str3 – then popped off
  for printAll
    for toString for str1 – then popped off
    for System.out.println – then popped off
  etc.
Activation Records– Example 2

• What will be in the activation record for **main**? (and in the heap?)
  • Address to return to in operating system
  • Variable **args**
  • Variable **str1**
    • Initially?
    • After return from *String constructor*?
  • Variable **str2**
  • Variable **str3**

• What will be in the activation record for **printAll**?
Memory Deallocation

• What happens when a method returns?
  • On the execution stack:
    • The activation record is automatically popped off when the method returns
  • So, that memory is deallocated
Memory Deallocation

• What happens to objects on the heap?
  • An object stays in the heap even if there is no longer a variable referencing it!
  • So, Java has automatic garbage collection
    • It regularly identifies objects which no longer have a variable referencing them, and deallocates that memory