

CSE201: Monsoon 2020
Advanced Programming

Lecture 18: Thread Creation

Vivek Kumar

Computer Science and Engineering

IIT Delhi

vivekk@iiitd.ac.in

Today's Lecture

- How to create your own thread in Java

Creating Threads in Java

```
public class MyThread implements java.lang.Runnable {  
    .....  
    @Override  
    public void run() { ..... }  
}
```

```
public class MyThread extends java.lang.Thread {  
    .....  
    @Override  
    public void run() { ..... }  
}
```

- There are two ways to create your own **Thread** object
 - Implementing the **Runnable** interface
 - Subclassing the **Thread** class and instantiating a new object of that class
- In both cases the **run()** method should be implemented

Sequential Array Sum Implementation

```
public class ArraySum {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void calculate() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
    {
        int size; int[] array; //allocated (size) & initialized
        ArraySum asum = new ArraySum(array, 0, size);
        asum.calculate();
        int result = asum.getResult();
    }
}
```

© Vivek Kumar

- This is a sequential code to find the sum of elements in an array
- Can we use multithreading here?
 - Which part of the code we can parallelize?
 - As the length of array grows huge, the execution time will start increasing

Parallel Array Sum Implementation (1/6)

```
public class ArraySum implements Runnable {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void calculate() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
    {
        int size; int[] array; //allocated (size) & initialized
        ArraySum asum = new ArraySum(array, 0, size);
        asum.calculate();
        int result = asum.getResult();
    }
}
```

© Vivek Kumar

- Lets parallelize the execution of “calculate” method by implementing Runnable interface
 - This method is the performance bottleneck as array length grows huge
- Step-1
 - Implement `java.lang.Runnable` interface

Parallel Array Sum Implementation (2/6)

```
public class ArraySum implements Runnable {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void run() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
    {
        int size; int[] array; //allocated (size) & initialized
        ArraySum asum = new ArraySum(array, 0, size);
        asum.calculate();
        int result = asum.getResult();
    }
}
```

● Step-2

- Implement the method “public void run()”
- This abstract method is in Runnable interface (no other methods there)
- For simplicity, we will rename “calculate” method in this example to “run”
 - Note that run() method is of void type
 - In next lecture we will see how to return results (or objects) from Threads

Parallel Array Sum Implementation (3/6)

```
public class ArraySum implements Runnable {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void run() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
    {
        int size; int[] array; //allocated (size) & initialized
        ArraySum left = new ArraySum(array, 0, size/2);
        ArraySum right = new ArraySum(array, size/2, size);
        Thread t1 = new Thread(left);
        Thread t2 = new Thread(right);

    }
}
```

● Step-3

- Create two threads (t1 & t2)
- java.lang.Thread class
- t1 will calculate the sum of left half of the array and t2 will calculate the sum of right half of array
 - Before creating t1 and t2 we must create objects of Runnable type that should be passed to the Thread constructor

Parallel Array Sum Implementation (4/6)

```
public class ArraySum implements Runnable {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void run() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
    {
        int size; int[] array; //allocated (size) & initialized
        ArraySum left = new ArraySum(array, 0, size/2);
        ArraySum right = new ArraySum(array, size/2, size);
        Thread t1 = new Thread(left);
        Thread t2 = new Thread(right);
        t1.start(); t2.start();
    }
}
```

● Step-4

- Start both the threads by calling the start() method in Thread class
- JVM now allows this thread to begin its execution
- JVM calls the run() method of this thread
 - Thread class also implements Runnable interface but has empty bodied run()
 - When a Thread is created using a Runnable object (as in this example), then run() implementation of that Runnable object is called

Parallel Array Sum Implementation (5/6)

```
public class ArraySum implements Runnable {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void run() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
        throws InterruptedException {
        int size; int[] array; //allocated (size) & initialized
        ArraySum left = new ArraySum(array, 0, size/2);
        ArraySum right = new ArraySum(array, size/2, size);
        Thread t1 = new Thread(left);
        Thread t2 = new Thread(right);
        t1.start(); t2.start();
        t1.join(); t2.join();
    }
}
```

© Vivek Kumar

● Step-5

- Wait for both the threads to complete their execution (i.e. wait for them to finish execution of run method)
 - join() method from Thread class is used for this purpose
 - join() method throws checked exception and hence main() must declare that

Parallel Array Sum Implementation (6/6)

```
public class ArraySum implements Runnable {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    public void run() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
        throws InterruptedException {
        int size; int[] array; //allocated (size) & initialized
        ArraySum left = new ArraySum(array, 0, size/2);
        ArraySum right = new ArraySum(array, size/2, size);
        Thread t1 = new Thread(left);
        Thread t2 = new Thread(right);
        t1.start(); t2.start();
        t1.join(); t2.join();
        int result = left.getResult() + right.getResult();
    }
}
```

© Vivek Kumar

- Step-6
 - Sum the partial results from each threads to get the final results
- What would happen if you call `t1.start()` followed by `t1.join()` and then similarly for thread `t2`?
 - Although there are two threads, still the program is sequential!
- Can you write this same program with more than two threads?

Parallel Array Sum By Subclassing Thread

```
public class ArraySum extends Thread {
    int[] array;
    int sum, low, high;
    public ArraySum(int[] arr, int l, int h) {
        array=arr; sum=0; low=l; high=h;
    }
    //assume array.length%2=0
    @Override
    public void run() {
        for(int i=low; i<high; i++)
            sum += array[i];
    }
    public int getResult() { return sum; }
    public static void main(String[] args)
        throws InterruptedException {
        int size; int[] array; //allocated (size) & initialized
        ArraySum t1 = new ArraySum(array, 0, size/2);
        ArraySum t2 = new ArraySum(array, size/2, size);
        t1.start(); t2.start();
        t1.join(); t2.join();
        int result = t1.getResult() + t2.getResult();
    }
}
```

- Only three changes are required
 1. Instead of implementing Runnable, now the ArraySum class will extend Thread class
 2. Override the run() method as Thread class also has empty-body implementation of run()
 3. ArraySum objects are themselves Thread objects and hence now no need to explicitly call constructor of Thread class

Runnable v/s Subclassing Thread

- **Multiple inheritance is not allowed in Java** hence if our ArraySum class extends Thread then it cannot extend any other class. By implementing Runnable our ArraySum can easily extend any other class
- **Subclassing is used in OOP to add additional feature,** modifying or improving behavior. If no modifications are being made to Thread class then use Runnable interface
- **Thread can only be started once.** Runnable is better as same object could be passed to different threads
- If just run() method has to be provided then **extending Thread class is an overhead for JVM**

Question: Any Issues Below?

```
.....  
class MyClass1 implements Runnable {  
    .....  
}  
class MyClass2 extends Thread {  
    .....  
}  
  
.....  
MyClass1 MyClass1Object = new MyClass1();  
Thread t1 = new Thread(MyClass1Object);  
t1.run()  
  
MyClass2 t2 = new MyClass2();  
t2.run();
```

- What would happen if we directly call run() method from Runnable or Thread object instead of start() and join()?
 - Neither a compilation or runtime error
 - No thread is created by JVM!
 - Sequential execution
 - **Calling start() method is mandatory !**

Question: Any Issues Below?

```
.....  
class MyClass1 implements Runnable {  
    .....  
}  
class MyClass2 extends Thread {  
    .....  
}  
  
.....  
MyClass1 MyClass1Object = new MyClass1();  
Thread t1 = new Thread(MyClass1Object);  
t1.start();  
t1.start();  
  
MyClass2 t2 = new MyClass2();  
t2.start();  
t2.start();
```

- **start() method cannot be invoked more than once**
 - A thread can't be restarted
 - Exception generated at runtime
 - **IllegalThreadStateException**
- Although we can create several threads with the same runnable type object
 - Advantage of implementing Runnable over extending Thread

Fibonacci Number Calculation

// Sequential Implementation of Fibonacci

```
public class Fibonacci {
    int result, n;
    public Fibonacci(int n) { this.n = n; }
    public static int fib(int n) {
        if(n<2) return n;
        else return fib(n-1) + fib(n-2);
    }
    public void calculate() {
        result = fib(n);
    }
    public int getResult() { return result; }
    public static void main(String[] args) {
        int n = 40;
        Fibonacci fib = new Fibonacci(n);
        int result = fib.getResult();
    }
}
```

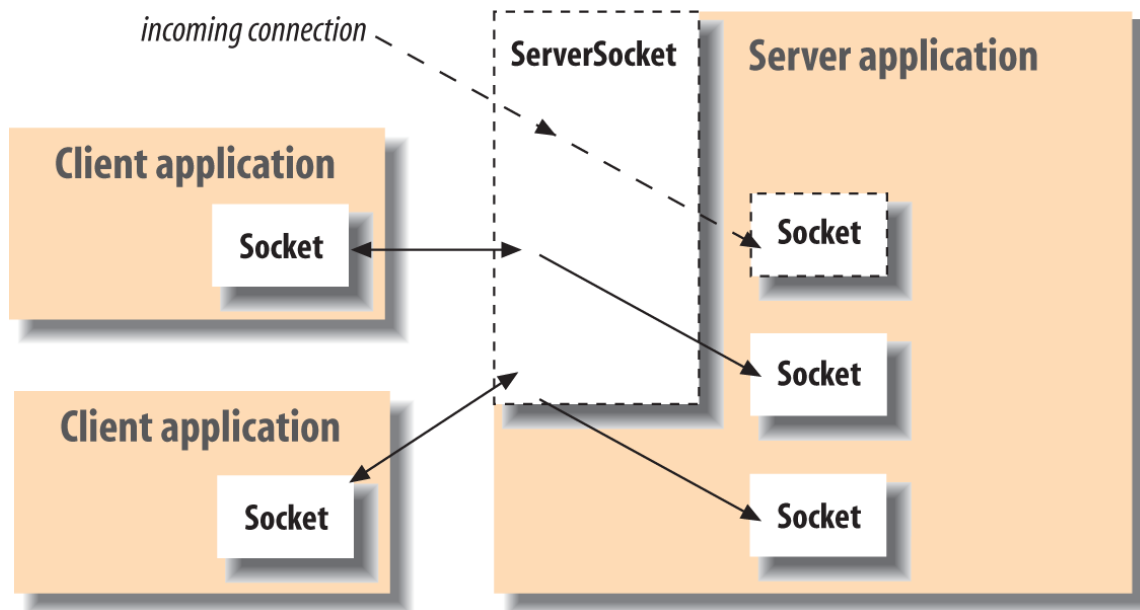
Is this an efficient
implementation of
parallel Fibonacci??

// Parallel Implementation of Fibonacci

```
public class Fibonacci implements Runnable {
    int result, n;
    public Fibonacci(int n) { this.n = n; }
    public static int fib(int n) {
        if(n<2) return n;
        else return fib(n-1) + fib(n-2);
    }
    public void run() {
        result = fib(n);
    }
    public int getResult() { return result; }
    public static void main(String[] args)
        throws InterruptedException {
        int n = 40;
        Fibonacci left = new Fibonacci(n-1);
        Fibonacci right = new Fibonacci(n-2);
        Thread t1 = new Thread(left);
        Thread t2 = new Thread(right);
        t1.start(); t2.start();
        t1.join(); t2.join();
        int result = left.getResult() + right.getResult();
    }
}
```

Golden Ratio!
 $\text{Fib}_{n+1}/\text{Fib}_n = 1.6$

Multithreading in Socket Programming



- Sockets provide the communication mechanism between two computers that are connected using a network
 - A two-way communication protocol
 - Communication between two processes
- A client program creates a socket on its end of the communication and attempts to connect that socket to a server
- When the connection is made, the server creates a socket object on its end of the communication
- The client and the server can now communicate by writing to and reading from the socket

Multithreaded Server Application (1/2)

```
import java.io.*;
import java.net.*;
public class Server {

    public static void main(String args[ ])
        throws IOException {
        /* create a server socket
        bound to the specified port 1234 */
        ServerSocket me = new ServerSocket(1234);
        /* Server is now listening
        for incoming client's request */
        while (true) {
            /* Connection is established */
            Socket connection = me.accept();
            System.out.println("Connected");
            /* Spawn a thread for every
            connecting client */
            new Handler(connection).connect();
        }
    }
}
```

```
class Handler {
    Socket connection;
    Handler(Socket connection) {
        this.connection = connection;
    }
    public void connect() throws IOException {
        DataOutputStream out = null;
        try {
            out=new DataOutputStream(connection.getOutputStream());
            out.writeUTF("Hello Client!!");
        } finally {
            out.close();
            connection.close();
        }
    }
}
```

Access stream in a machine independent way

Is this an efficient implementation of server ??

Multithreaded Server Application (2/2)

```
import java.io.*;
import java.net.*;
public class Server {

    public static void main(String args[ ])
        throws IOException {
        /* create a server socket
           bound to the specified port 1234 */
        ServerSocket me = new ServerSocket(1234);
        /* Server is now listening
           for incoming client's request */
        while (true) {
            /* Connection is established */
            Socket connection = me.accept();
            System.out.println("Connected");
            /* Spawn a thread for every
               connecting client */
            Thread t=new Thread(new Handler(connection));
            t.start();
        }
    }
}
```

```
class Handler implements Runnable {
    Socket connection;
    Handler(Socket connection) {
        this.connection = connection;
    }
    public void run() throws IOException {
        DataOutputStream out = null;
        try {
            out=new DataOutputStream(connection.getOutputStream());
            out.writeUTF("Hello Client!!");
        } finally {
            out.close();
            connection.close();
        }
    }
}
```

Client Application

```
import java.io.*;
import java.net.*;

public class Client {

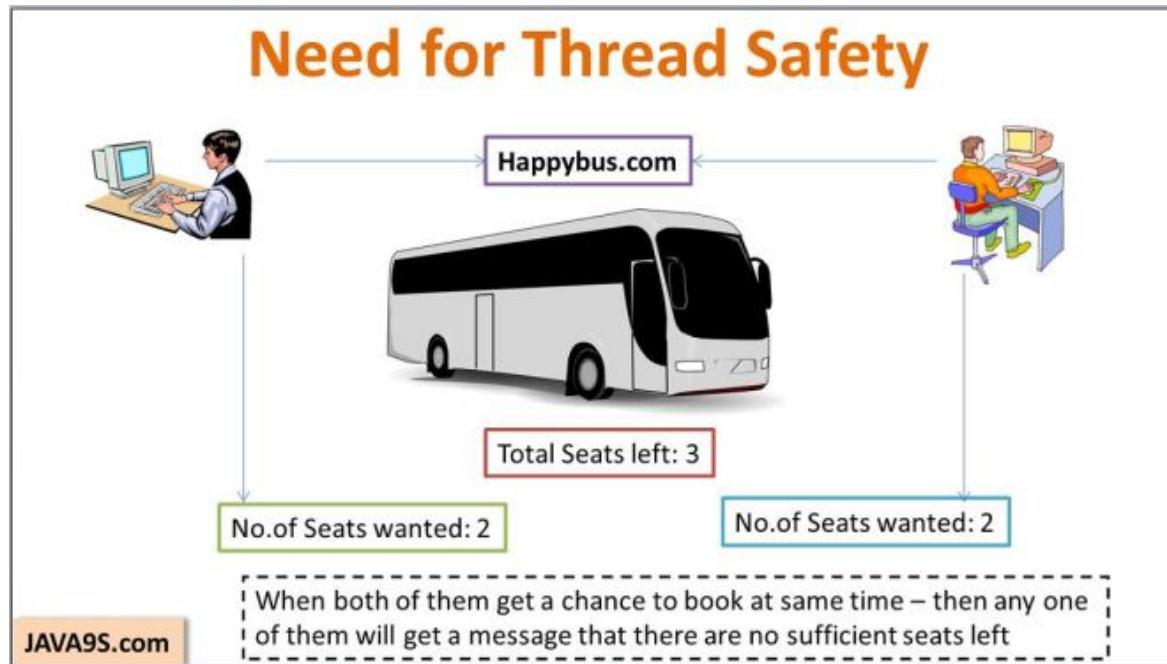
    public static void main(String args[ ])
        throws IOException {
        String serverName = "localhost"; //or remote IP Address
        int port = 1234; // should be same as used in server
        /* Connect to server that is already listening */
        Socket server = new Socket(serverName, port);
        System.out.println("Just connected to " +
            server.getRemoteSocketAddress());
        DataInputStream in = new
            DataInputStream(server.getInputStream());
        System.out.println("Server says " + in.readUTF());
        in.close();
        /* close connection with server */
        server.close();
    }
}
```

- Why our server application was missing the join() for the threads it spawned for every new client connection ?
 - Will the server be able to serve multiple clients in parallel?

Some Other Methods in Thread

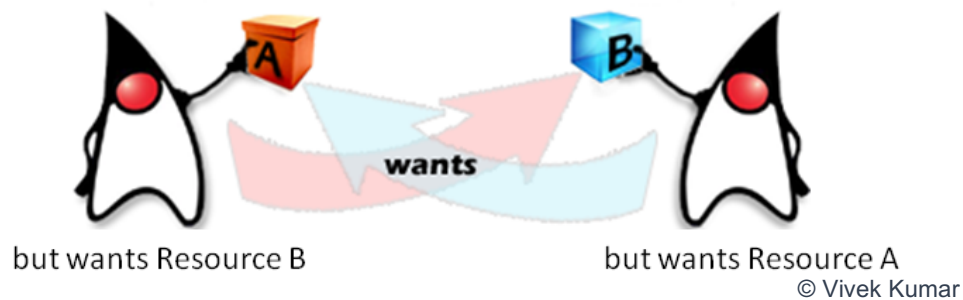
- `static Thread currentThread()`
 - Returns a reference to the currently executing thread object
- `long getId()`
 - Returns the identifier of this thread
- `static void sleep(long millisec)`
 - Causes the currently executing thread to sleep (temporarily cease execution) for the specified number of milliseconds

Disadvantages of Multithreading



Thread 1 is holding Resource A

Thread 2 is holding Resource B



- It is hard to debug and test a multithreaded program
- Sometimes unpredictable results
 - Race conditions
 - Lecture 20
- Chances of deadlock
 - Lecture 20

Next Lecture

- Thread pool in Java
 - `java.util.*` classes specific to `ThreadPool` implementation