# CMSC 132:
# OBJECT-ORIENTED PROGRAMMING II


## Threads in Java

Department of Computer Science
University of Maryland, College Park

## Problem

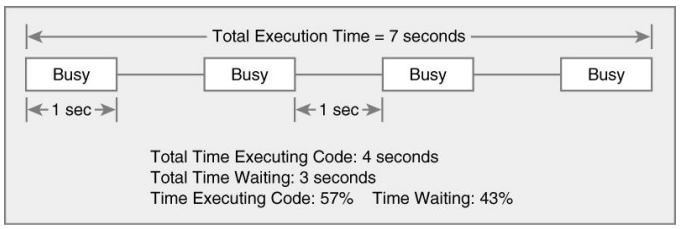
- Multiple tasks for computer
  - Draw & display images on screen
  - Check keyboard & mouse input
  - Send & receive data on network
  - Read & write files to disk
  - Perform useful computation (editor, browser, game)
- How does computer do everything at once?
  - Multitasking
  - Multiprocessing

# Multitasking (Time-Sharing)

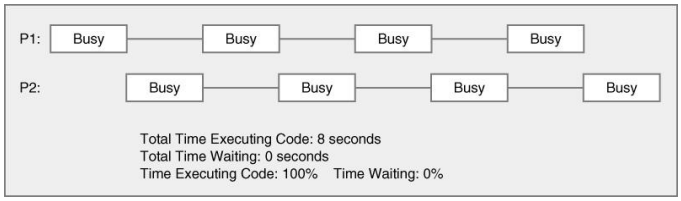
- Approach
  - Computer does some work on a task
  - Computer then quickly switch to next task
  - Tasks managed by operating system (scheduler)
- Computer seems to work on tasks concurrently
- Can improve performance by reducing waiting

# Multitasking Can Aid Performance

- Single task




- Two tasks



# Multiprocessing (Multithreading)

- Approach
  - Multiple processing units (multiprocessor)
  - Computer works on several tasks in parallel
  - Performance can be improved


**Dual-core AMD Athlon X2**

**32 processor Pentium Xeon**


**Titan at ORNL**

# Perform Multiple Tasks Using Processes

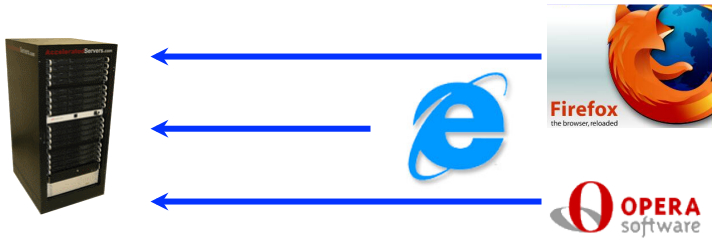
- Process
  - Definition → executable program loaded in memory
  - Has own address space
    - Variables & data structures (in memory)
  - Each process may execute a different program
  - Communicate via operating system, files, network
  - May contain multiple threads

## Perform Multiple Tasks Using Threads

- Thread
  - Definition → sequentially executed stream of instructions
  - Has own execution context
    - Program counter, call stack (local variables)
  - Communicate via shared access to data
  - Also known as “lightweight process”

## Motivation for Multithreading

- Captures logical structure of problem
  - May have concurrent interacting components
  - Can handle each component using separate thread
  - Simplifies programming for problem
- Example




**Web Server uses threads to handle …**

**Multiple simultaneous web browser requests**

# Motivation for Multithreading

- Better utilize hardware resources
  - When a thread is delayed, compute other threads
  - Given extra hardware, compute threads in parallel
  - Reduce overall execution time
- Example


**Multiple simultaneous web browser requests…**

**Handled faster by multiple web servers**

# Programming with Threads

- Concurrent programming
  - Writing programs divided into independent tasks
  - Tasks may be executed in parallel on multiprocessors
- Multithreading
  - Executing program with multiple threads in parallel
  - Special form of multiprocessing

# Creating Threads in Java

- Two approaches to create threads
  - Extending Thread class (**NOT RECOMMENDED**)
  - Runnable interface approach (**PREFERED**)
- Approach 1: Extending Thread class
  - We overload the Thread class run() method
  - The run() methods defines the actual task the thread performs
  - Example

```
public class MyT extends Thread {
    public void run( ) {
        …                    // work for thread
    }
}
MyT t = new MyT( ) ;   // create thread
t.start( );            // begin running thread
…                      // thread executing in parallel
```

- **Example:** message, messageThreadExtends packages

# Creating Threads in Java

- Approach 2: Runnable Interface
  - Define a class (worker) that implements the Runnable interface

```
public interface Runnable {
    public void run();   // work done by thread
}
```

  - Create thread to execute the run() method
    - Alternative 1: Create thread object and pass worker object to Thread constructor
    - Alternative 2: Hand worker object to an executor
  - Example

```
public class Worker implements Runnable {
    public void run( )  { // work for thread }
}
Thread t = new Thread(new Worker( ));  // create thread
t.start();                             // begin running thread
…                                      // thread executing in parallel
```

- **Example:** message, messageThreadRunnable packages

## Why Extending Thread Approach Not Recommended?

- Not a big problem for getting started
  - But a bad habit for industrial strength development
- Methods of worker and Thread class intermixed
- Hard to migrate to more efficient approaches
  - Thread Pools

## Thread Class

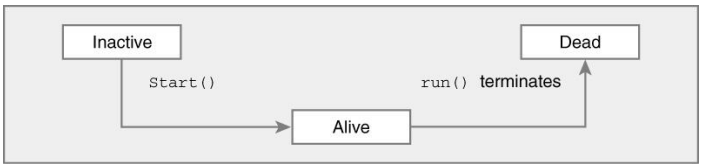
```
public class Thread extends Object implements Runnable {
    public Thread();
    public Thread(String name);   // Thread name
    public Thread(Runnable R);
    public Thread(Runnable R, String name);

    public void run();     // if no R, work for thread
    public void start();   // thread gets in line so it eventually it can run
    ...
}
```

# More Thread Class Methods

```
public class Thread extends Object {
    …
    public static Thread currentThread()
    public String getName()
    public void interrupt()  // alternative to stop (deprecated)
    public boolean isAlive()
    public void join()
    public void setDaemon()
    public void setName()
    public void setPriority()
    public static void sleep()
    public static void yield()
}
```

# Creating Threads in Java

- Note
  - Thread eventually starts executing only if start() is called



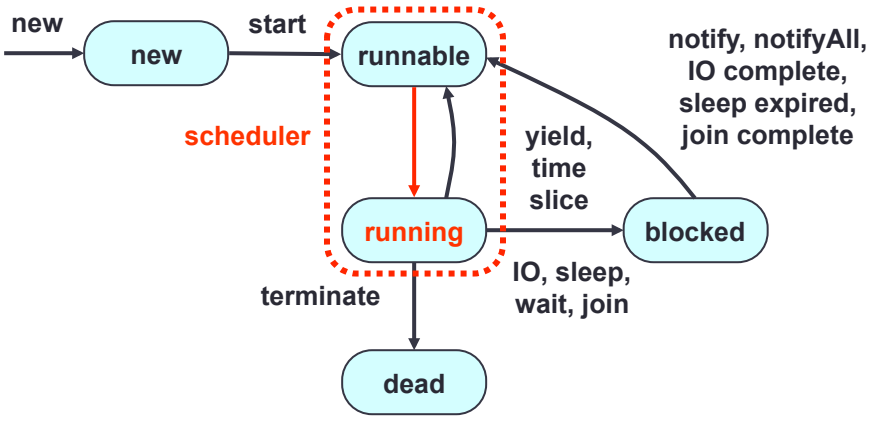

  - Runnable is interface
    - So it can be implemented by any class
    - Required for multithreading in applets
  - Do not call the run method directly

# Threads – Thread States

- Java thread can be in one of these states
  - New → thread allocated & waiting for start()
  - Runnable → thread can begin execution
  - Running → thread currently executing
  - Blocked → thread waiting for event (I/O, etc.)
  - Dead → thread finished
- Transitions between states caused by
  - Invoking methods in class Thread
    - new(), start(), yield(), sleep(), wait(), notify()…
  - Other (external) events
    - Scheduler, I/O, returning from run()…
- In Java states defined by Thread.State
  http://docs.oracle.com/javase/7/docs/api/java/lang/Thread.State.html

# Threads – Thread States

- State diagram




**Running is a logical state → indicates runnable thread is actually running**

## Daemon Threads

- Java threads types
  - User
  - Daemon
    - Provide general services
    - Typically never terminate
    - Call setDaemon() before start()
- Program termination
  - All user threads finish
  - Daemon threads are terminated by JVM

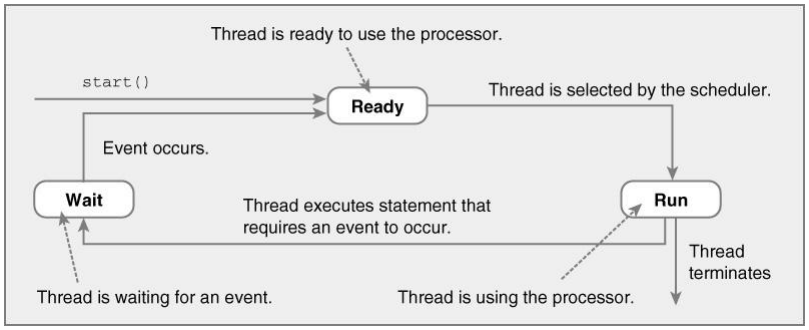
## Threads – Scheduling

- Scheduler
  - Determines which runnable threads to run
    - When context switching takes place
  - Can be based on thread priority
  - Part of OS or Java Virtual Machine (JVM)

- Scheduling policy
  - Non-preemptive (cooperative) scheduling
  - Preemptive scheduling

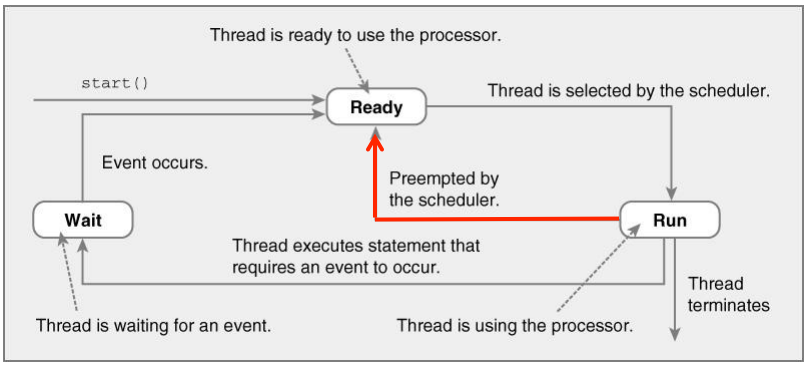
# Threads – Non-preemptive Scheduling

- Threads continue execution until
  - Thread terminates
  - Executes instruction causing wait (e.g., IO)
  - Thread volunteering to stop (invoking yield or sleep)




# Threads – Preemptive Scheduling

- Threads continue execution until
  - Same reasons as non-preemptive scheduling
  - Preempted by scheduler



## Thread Scheduling Observations

- Order thread is selected is indeterminate
  - Depends on scheduler
- Scheduling may not be fair
  - Some threads may execute more often
- Thread can block indefinitely (starvation)
  - If other threads always execute first
- Your code should work correctly regardless the scheduling policy in place

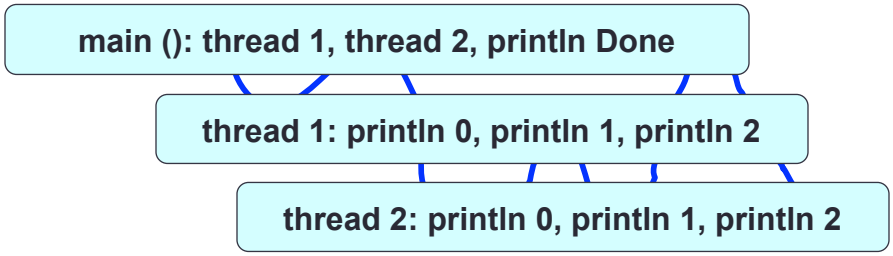
## Java Thread Example

```
public class ThreadNoJoin extends Thread {
   public void run() {
      for (int i = 0; i < 3; i++) {
         try {
            sleep((int)(Math.random() * 5000)); // 5 secs
         } catch (InterruptedException e) { e.printStackTrace(); }
         System.out.println(i);
      }
   }
   public static void main(String[] args) {
      Thread t1 = new ThreadNoJoin();
      Thread t2 = new ThreadNoJoin();
      t1.start();
      t2.start();
      System.out.println("Done");
   }
}
```

To understand this example better, let's assume we want to make a sandwich

## Java Thread Example – Output

- Possible outputs
  - 0,1,2,0,1,2,Done // thread 1, thread 2, main()
  - 0,1,2,Done,0,1,2 // thread 1, main(), thread 2
  - Done,0,1,2,0,1,2 // main(), thread 1, thread 2
  - 0,0,1,1,2,Done,2 // main() & threads interleaved




## Thread Class – join( ) Method

- Can wait for thread to terminate with join( )
- Method prototype
  - public final void join( )
    - Returns when thread is done
    - Throws InterruptedException if interrupted

# Java Thread Example (Join)

```
public class ThreadJoin extends Thread {
        public void run() {
           for (int i = 0; i < 3; i++) {
              try {
                 sleep((int)(Math.random() * 5000)); // 5 secs
               } catch (InterruptedException e) { e.printStackTrace(); }
              System.out.println(i);
           }
        }

        public static void main(String[] args) {
           Thread t1 = new ThreadJoin();
           Thread t2 = new ThreadJoin();
           t1.start();
           t2.start();
           try {
              t1.join();
              t2.join();
           } catch (InterruptedException e) { e.printStackTrace(); }
           System.out.println("Done");
        }
}
```

# About Join

- Important: You will limit the concurrency level if you do not start/join correctly
- Suppose you want to run many threads concurrently. **Start them all and then execute the join for each one**. **Do not start one thread, then join on that thread, start the second one, join on that thread, etc.**
- The following is WRONG!

  t1.start()
  t1.join()
  t2.start()
  t2.join()
- Feel free to use arrays, sets, etc., to keep track of your threads

# Terminating Threads

- A thread ends when the run() method ends
- Sometimes we may need to stop a thread before it ends
  - For example, you may have created several threads to find a problem solution and once one thread finds it, there is no need for the rest
- How to stop thread?
  - **Using stop() method** → WRONG! This is a deprecated method. Using it can lead to problems when data is shared
  - **Using interrupt() method**
    - This method does not stop the thread. Instead, it notifies the thread that it should terminate. The method sets a boolean variable in the thread and that value can be checked by the thread (by using the method interrupted())
    - It is up to the thread to terminate or not
    - public void run() {

```
while(!Thread.interrupted()) {
    // work
}
// release resource, cleaning tasks
}
```

# Thread Example

- Swing uses a single-threaded model
- Long computations in the EDT freezes the GUI
- Example: Progress Bar Example