

CMSC 433 – Programming Language
Technologies and Paradigms
Fall 2003

Threads and Synchronization

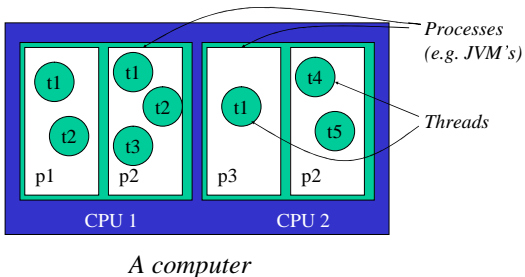
(thanks to Doug Lea for some slides)

Overview

- What are threads?
 - Concept
 - Basic Java mechanisms
- Thread concerns
 - Safety and Liveness
 - Use of synchronization and signalling
- Threading design patterns

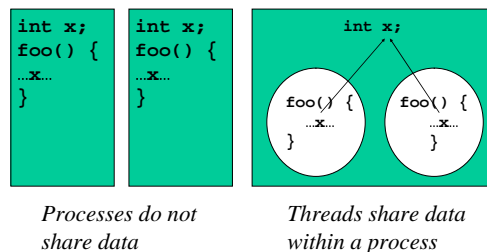
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Computation Abstractions



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Processes vs. Threads



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So, what is a thread?

- **Conceptually:** it is a parallel computation occurring within a process
- **Implementation view:** it's a program counter and a stack. The heap and static area are shared among all threads
- All programs have at least one thread (main)

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Why multiple threads?

- Performance:
 - Parallelism on multiprocessors
 - Concurrency of computation and I/O
- Can easily express some programming paradigms
 - Event processing
 - Simulations
- Keep computations separate, as in an OS
 - Java OS

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Why not multiple threads?

- Complexity:
 - Dealing with safety, liveness, composition
- Overhead
 - Higher resource usage
- We'll compare threads to their alternatives a bit later ...

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Programming Threads

- Threads are available in many languages
 - C, C++, Objective Caml, Java, SmallTalk ...
- In many languages (e.g., C and C++), threads are a platform specific add-on
 - Not part of the language specification
- Part of the Java language specification

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Java Threads

- Every application has at least one thread
 - The “main” thread, started by the JVM to run the application's **main()** method.
- The code executed by **main()** can create other threads
 - Explicitly, using the **Thread** class
 - Implicitly, by calling libraries that create threads as a consequence
 - RMI, AWT/Swing, Applets, etc.

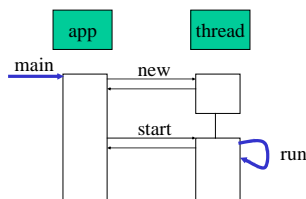
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Java Threads: Creation

- To explicitly create a thread
 - Instantiate a **Thread** object
 - Invoke the object's **start()** method
 - This will start executing the **Thread's run()** method concurrently with the current thread
 - Thus, need to provide a **run()** method
 - Easy: subclass **Thread** and override **run()**.

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Java Threads: Creation



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Example: Synchronous alarms

```
while (true) {
    System.out.print("Alarm> ");

    // read user input
    String line = b.readLine();
    parseInput(line); // sets timeout

    // wait (in secs)
    try {
        Thread.sleep(timeout * 1000);
    } catch (InterruptedException e) { }
    System.out.println("(" + timeout + " " + msg);
}
```

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Making it Threaded (1)

```
public class AlarmThread extends Thread {
    private String msg = null;
    private int timeout = 0;

    public AlarmThread(String msg, int time) {
        this.msg = msg;
        this.timeout = time;
    }

    public void run() {
        try {
            Thread.sleep(timeout * 1000);
        } catch (InterruptedException e) { }
        System.out.println(""+timeout+" "+msg);
    }
}
```

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Making it Threaded (2)

```
while (true) {
    System.out.print("Alarm> ");

    // read user input
    String line = b.readLine();
    // creates a AlarmThread to wait timeout secs
    Thread t = parseInput(line);

    // wait for alarm concurrently
    if (t != null)
        t.start();
}
```

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Alternative: the Runnable interface

- Extending **Thread** prohibits a different parent
- Instead implement **Runnable**
 - declares that the class has a **void run()** method
- Can construct a new **Thread**
 - and give it an object of type **Runnable** as an argument to the constructor
 - **Thread(Runnable target)**
 - **Thread(Runnable target, String name)**

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Thread example revisited

```
public class AlarmRunnable implements Runnable {
    private String msg = null;
    private int timeout = 0;

    public AlarmRunnable(String msg, int time) {
        this.msg = msg;
        this.timeout = time;
    }

    public void run() {
        try {
            Thread.sleep(timeout * 1000);
        } catch (InterruptedException e) { }
        System.out.println(""+timeout+" "+msg);
    }
}
```

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Change is in parseInput

- Old parseInput does
 - return new AlarmThread(m,t);
- New parseInput does
 - return new Thread(new AlarmRunnable(m,t));
- Code in while loop doesn't change

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Notes: Passing Parameters

- **run()** doesn't take parameters
- We "pass parameters" to the new thread by storing them as private fields
 - In the extended class
 - Or the **Runnable** object
 - Example: the time to wait and the message to print in the AlarmThread class

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Thread Scheduling

- Once a new thread is created, how does it interact with existing threads?
- This is a question of scheduling:
 - Given N processors and M threads, which thread(s) should be run at any given time?

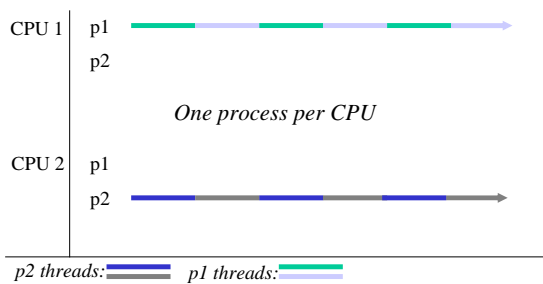
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Thread Scheduling

- OS schedules a single-threaded process on a single processor
- Multithreaded process scheduling:
 - One thread per processor
 - Effectively splits a process across CPU's
 - Exploits hardware-level concurrency
 - Many threads per processor
 - Need to share CPU in slices of time

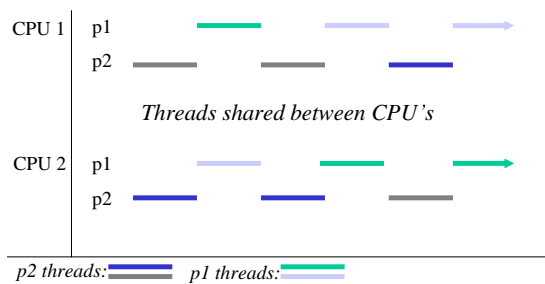
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Scheduling Example (1)



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Scheduling Example (2)



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Scheduling Consequences

- Concurrency
 - Different threads from the same application can be running *at the same time* on different processors
- Interleaving
 - Threads can be **pre-empted** at any time in order to schedule other threads

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Thread scheduling

- When multiple threads share a CPU, must decide:
 - When the current thread should stop running
 - What thread to run next
- A thread can voluntarily **yield()** the CPU
 - call to yield may be ignored; don't depend on it
- *Preemptive schedulers* can de schedule the current thread at any time
 - Not all JVMs use preemptive scheduling, so a thread stuck in a loop may *never* yield by itself. Therefore, put **yield()** into loops
- Threads are de scheduled whenever they block (e.g., on a lock or on I/O) or go to sleep

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Thread Lifecycle

- While a thread executes, it goes through a number of different phases
 - **New**: created but not yet started
 - **Runnable**: is running, or can run on a free CPU
 - **Blocked**: waiting for I/O or on a lock
 - **Sleeping**: paused for a user specified interval
 - **Terminated**: completed

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Which thread to run next?

- The scheduler looks at all of the runnable threads, including threads that were unblocked because
 - A lock was released
 - I/O became available
 - They finished sleeping, etc.
- Of these threads, it considers the thread's priority. This can be set with **setPriority()**. Higher priority threads get preference.
 - Oftentimes, threads waiting for I/O are also preferred.

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Simple thread methods

- void start()
- boolean isAlive()
- void setPriority(int newPriority)
 - thread scheduler might respect priority
- void join() throws InterruptedException
 - waits for a thread to die/finish

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Example: threaded, sync alarm

```
while (true) {
    System.out.print("Alarm> ");

    // read user input
    String line = b.readLine();
    Thread t = parseInput(line);

    // wait (in secs) asynchronously
    if (t != null)
        t.start();
    // wait for the thread to complete
    t.join();
}
```

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Simple static thread methods

- void yield()
 - Give up the CPU
- void sleep(long milliseconds) throws InterruptedException
 - Sleep for the given period
- Thread.currentThread()
 - Thread object for currently executing thread
- All apply to thread invoking the method

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Daemon threads

- void setDaemon(boolean on)
 - Marks thread as a daemon thread
 - Must be set before thread started
- By default, thread acquires status of thread that spawned it
- Program execution terminates when no threads running except daemons

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