Multithreaded Programming using Java Threads

CSC207 – Software Design

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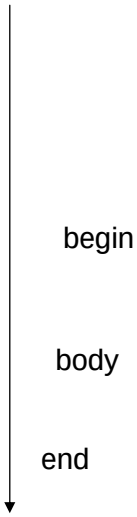
Agenda

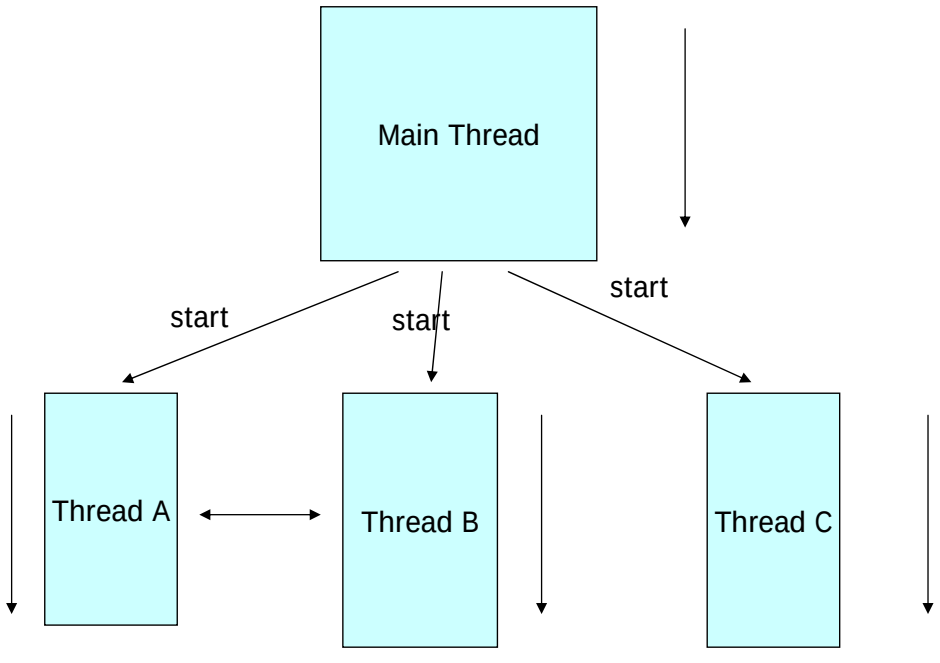
- Introduction
- Thread Applications
- Defining Threads
- Java Threads and States
  - Priorities
- Accessing Shared Resources
  - Synchronisation
- Assignment 1:
  - Multi-Threaded Math Server
- Advanced Issues:
  - Concurrency Models: master/worker, pipeline, peer processing
  - Multithreading Vs multiprocessing

A single threaded program

```
class ABC
{
....
    public void main(..)
    {
    ...
    ..
    }
}
```



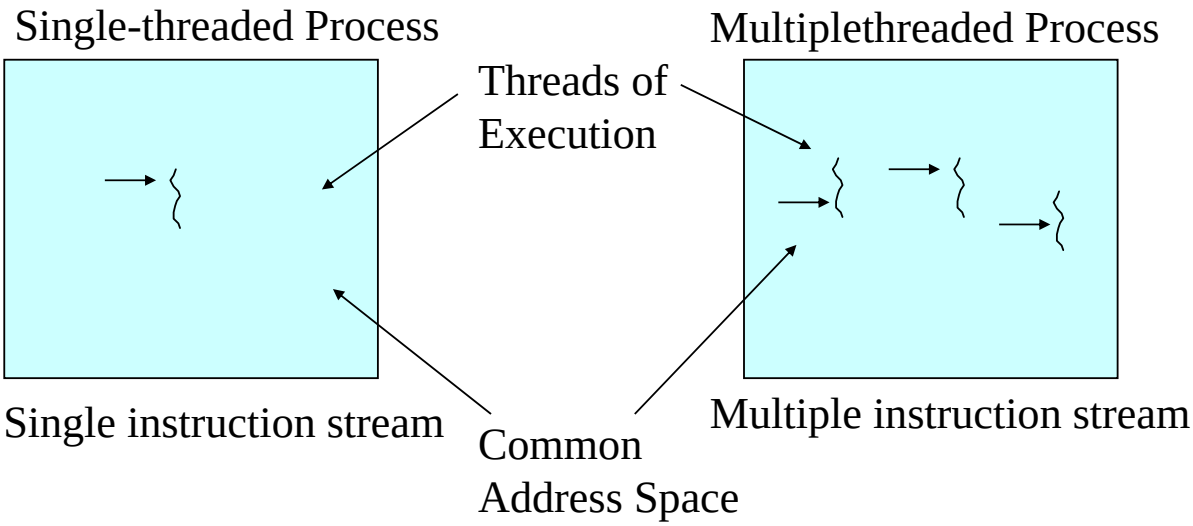
A Multithreaded Program



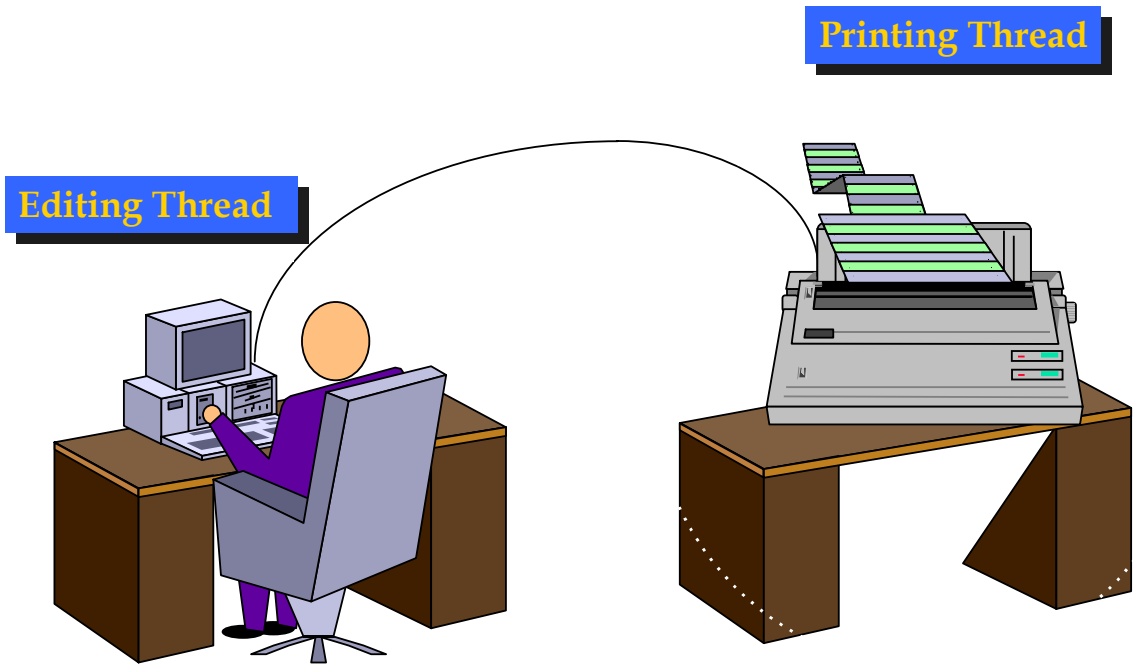
Threads may switch or exchange data/results

Single and Multithreaded Processes

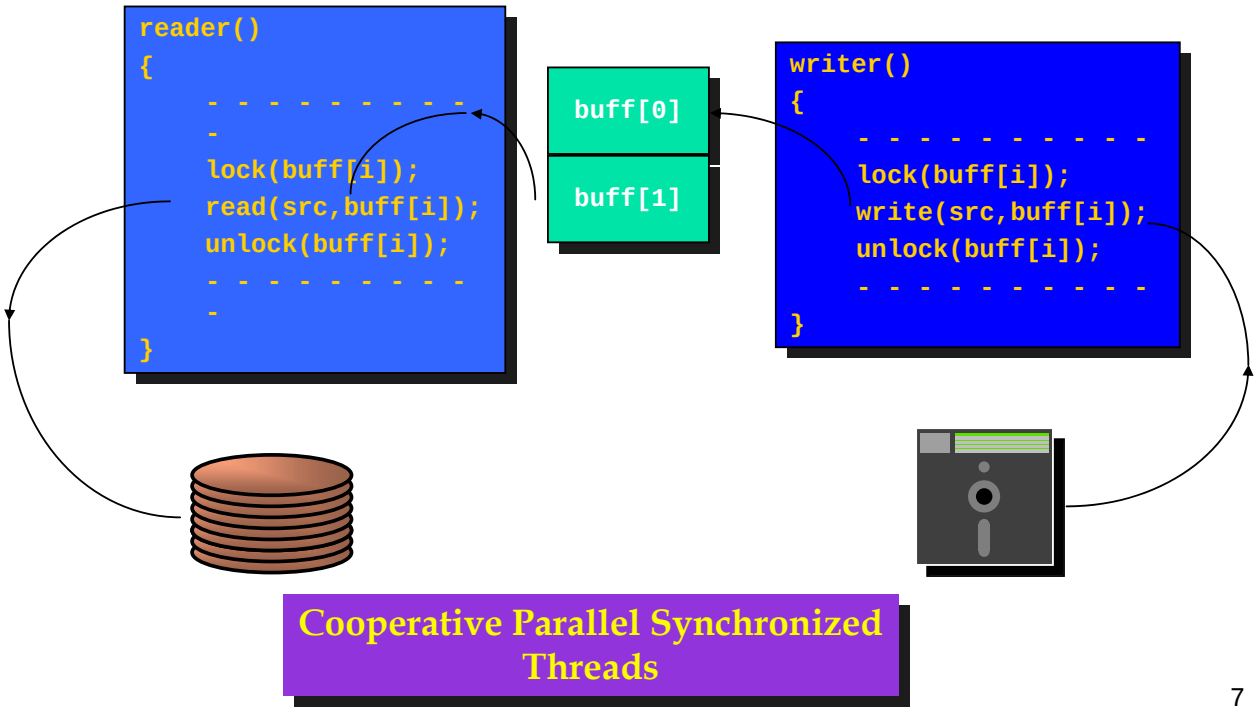
threads are light-weight processes within a process



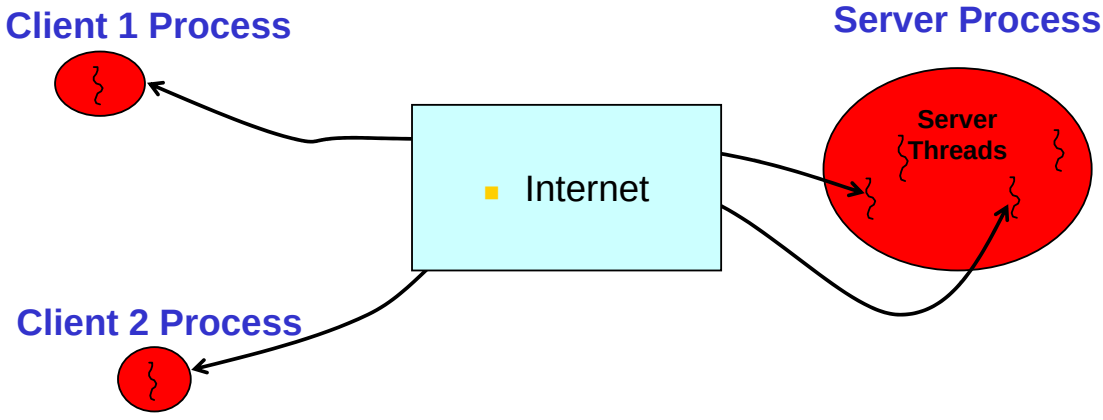
Modern Applications need Threads (ex1): Editing and Printing documents in background.



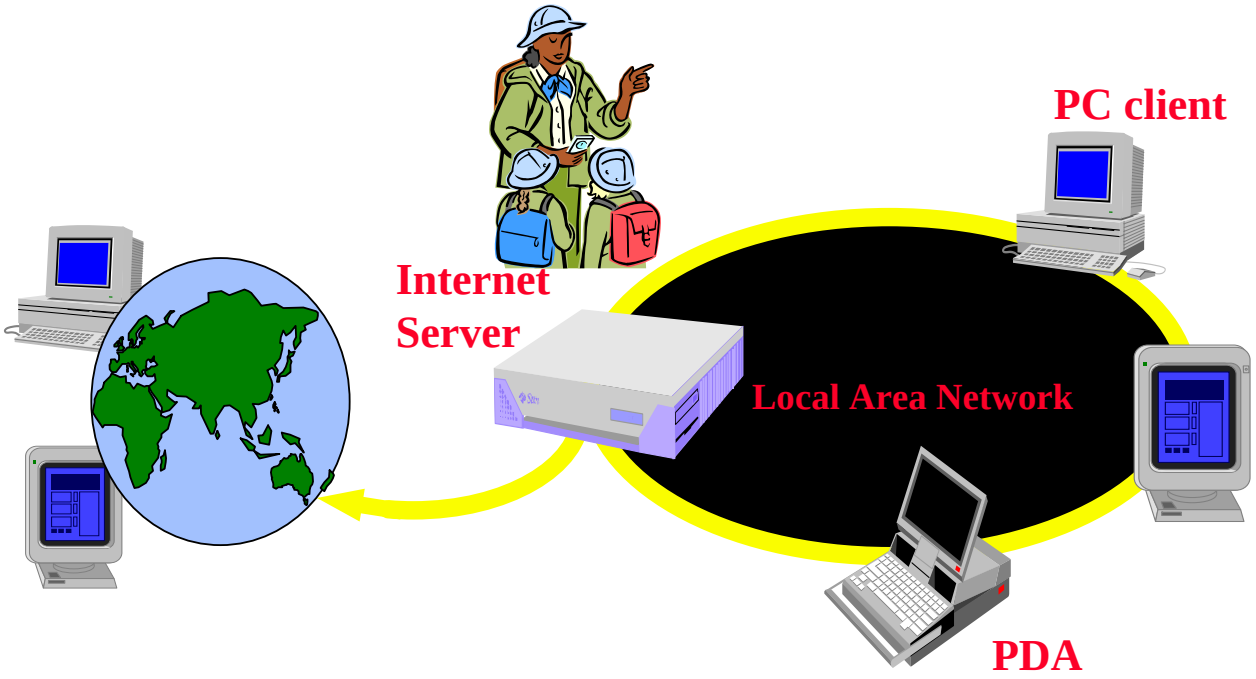
Multithreaded/Parallel File Copy



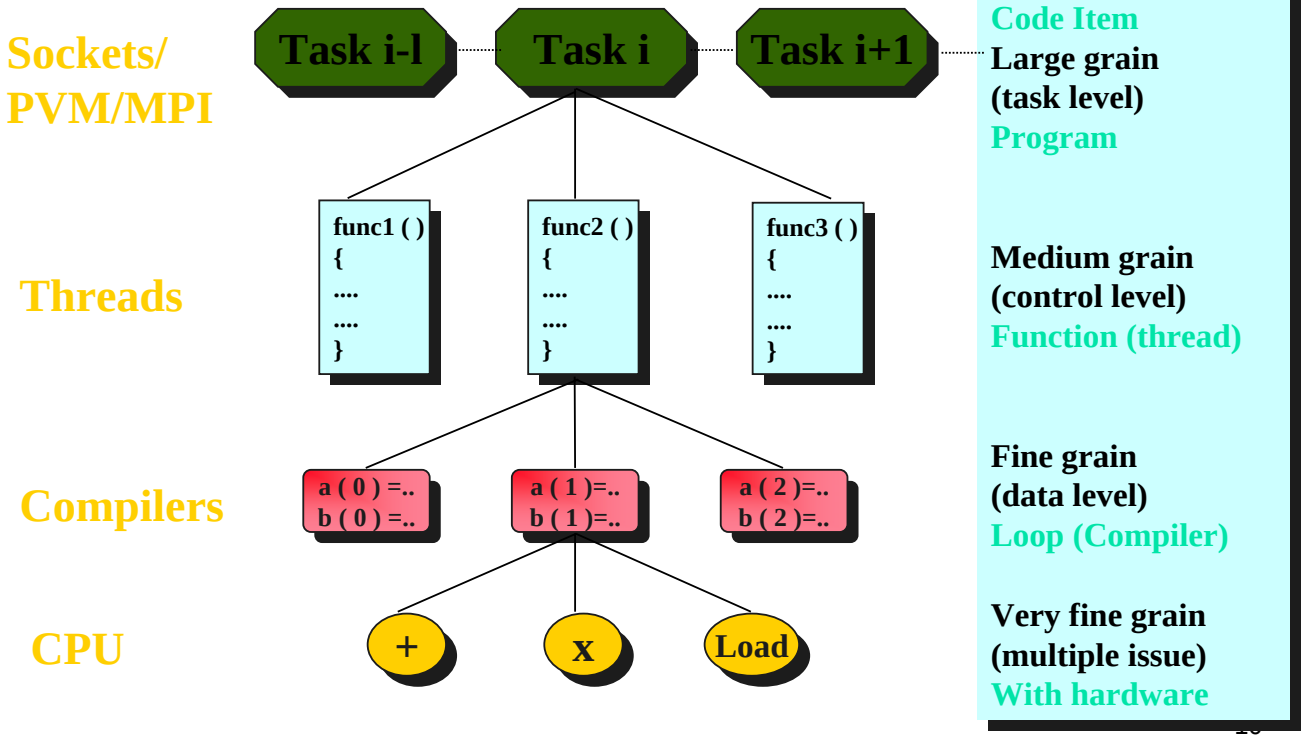
Multithreaded Server: For Serving Multiple Clients Concurrently



Web/Internet Applications: Serving Many Users Simultaneously



Levels of Parallelism



What are Threads?

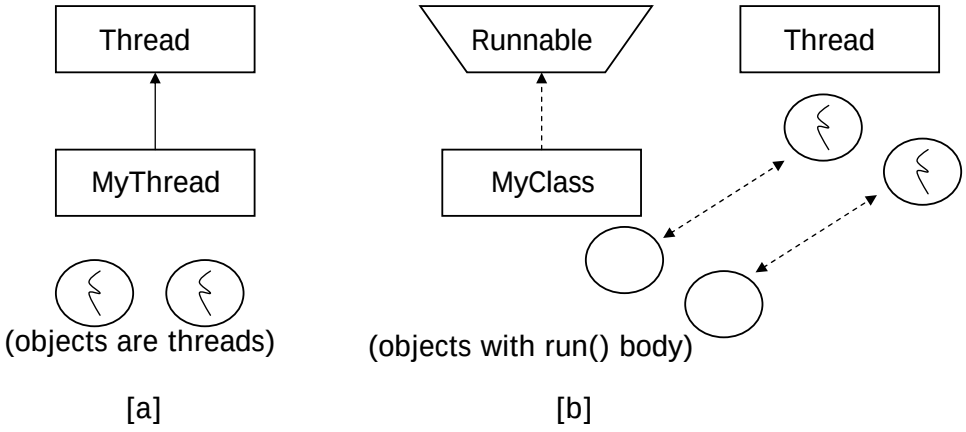
- A piece of code that run in concurrent with other threads.
- Each thread is a statically ordered sequence of instructions.
- Threads are being extensively used express concurrency on both single and multiprocessors machines.
- Programming a task having multiple threads of control – Multithreading or Multithreaded Programming.

Java Threads

- Java has built in thread support for Multithreading
- Synchronization
- Thread Scheduling
- Inter-Thread Communication:
  - currentThread
  - yield
  - sleep
  - resume
  - start
  - run
  - stop
  - setPriority
  - getPriority
  - suspend
- Java Garbage Collector is a low-priority thread.

Threading Mechanisms...

- Create a class that extends the Thread class
- Create a class that implements the Runnable interface



1st method: Extending Thread class

- Create a class by extending Thread class and override run() method:

```
class MyThread extends Thread
{
    public void run()
   {
      // thread body of execution
   }
}
```

- Create a thread:

```
MyThread thr1 = new MyThread();
```

- Start Execution of threads:

```
thr1.start();
```

- Create and Execute:

```
new MyThread().start();
```

An example

```
class MyThread extends Thread {
        public void run() {
                System.out.println(" this thread is running ... ");
        }
}

class ThreadEx1 {
        public static void main(String [] args  ) {
           MyThread t = new MyThread();
            t.start();
       }
}
```


2nd method: Threads by implementing Runnable interface

- Create a class that implements the interface Runnable and override run() method:

```
class MyThread implements Runnable
{
  .....
  public void run()
  {
     // thread body of execution
  }
}
```

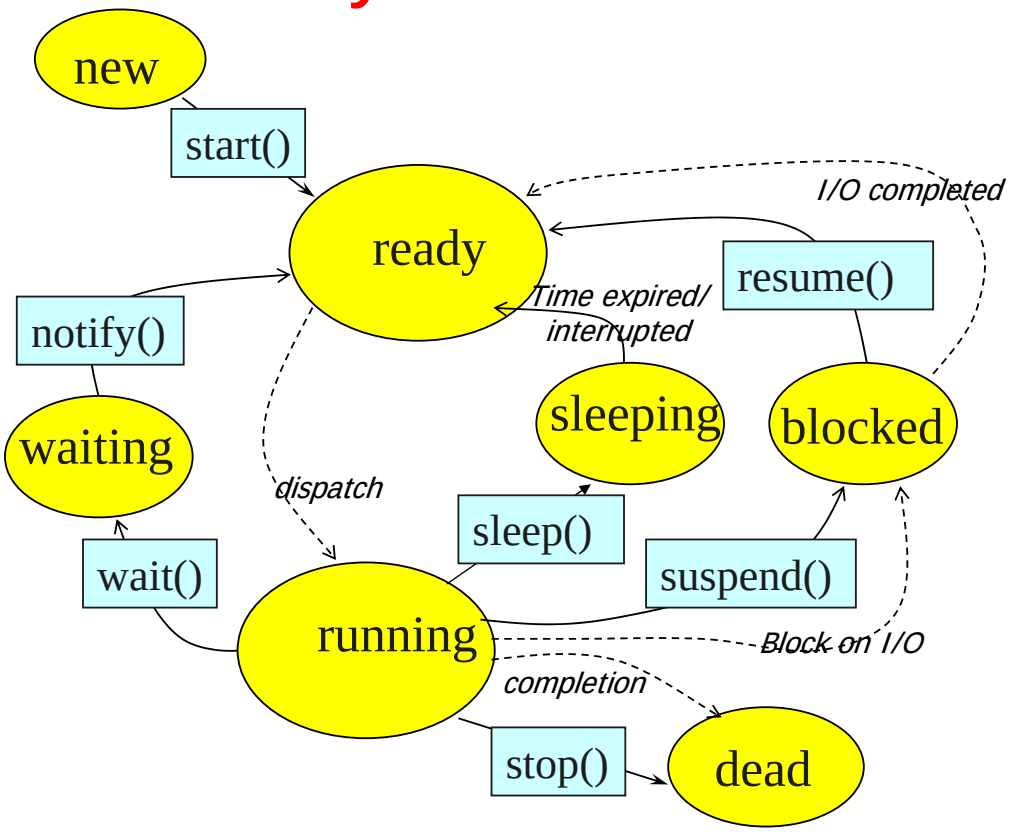
- Creating Object:
  `MyThread myObject = new MyThread();`
- Creating Thread Object:
  `Thread thr1 = new Thread( myObject );`
- Start Execution:
  `thr1.start();`

An example

```
class MyThread implements Runnable  {
        public void run() {
                System.out.println(" this thread is running ... ");
        }
}

class ThreadEx2 {
        public static void main(String [] args  ) {
                Thread t = new Thread(new MyThread());
                 t.start();
        }
}
```


Life Cycle of Thread



A Program with Three Java Threads

- Write a program that creates 3 threads

Three threads example

```
class A extends Thread
{
    public void run()
     {
        for(int i=1;i<=5;i++)
         {
            System.out.println("\t From ThreadA: i= "+i);
         }
         System.out.println("Exit from A");
     }
}

class B extends Thread
{
    public void run()
     {
        for(int j=1;j<=5;j++)
         {
            System.out.println("\t From ThreadB: j= "+j);
         }
         System.out.println("Exit from B");
     }
}
```

```
class C extends Thread
{
     public void run()
      {
         for(int k=1;k<=5;k++)
          {
              System.out.println("\t From ThreadC: k= "+k);
          }

           System.out.println("Exit from C");
       }
}

class ThreadTest
{
       public static void main(String args[])
        {
              new A().start();
              new B().start();
              new C().start();
        }
}
```


Run 1

- [raj@mundroo] threads [1:76] java ThreadTest

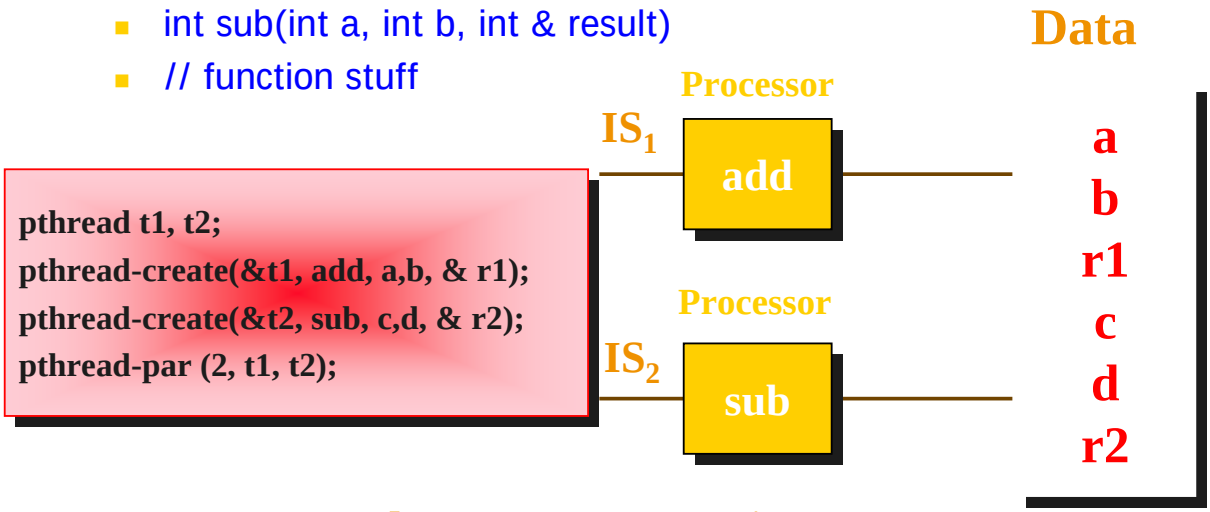
```
        From ThreadA: i= 1
        From ThreadA: i= 2
        From ThreadA: i= 3
        From ThreadA: i= 4
        From ThreadA: i= 5
Exit from A
        From ThreadC: k= 1
        From ThreadC: k= 2
        From ThreadC: k= 3
        From ThreadC: k= 4
        From ThreadC: k= 5
Exit from C
        From ThreadB: j= 1
        From ThreadB: j= 2
        From ThreadB: j= 3
        From ThreadB: j= 4
        From ThreadB: j= 5
Exit from B
```

Run2

- [raj@mundroo] threads [1:77] java ThreadTest
  From ThreadA: i= 1
  From ThreadA: i= 2
  From ThreadA: i= 3
  From ThreadA: i= 4
  From ThreadA: i= 5
  From ThreadC: k= 1
  From ThreadC: k= 2
  From ThreadC: k= 3
  From ThreadC: k= 4
  From ThreadC: k= 5
Exit from C
  From ThreadB: j= 1
  From ThreadB: j= 2
  From ThreadB: j= 3
  From ThreadB: j= 4
  From ThreadB: j= 5
Exit from B
Exit from A

Process Parallelism

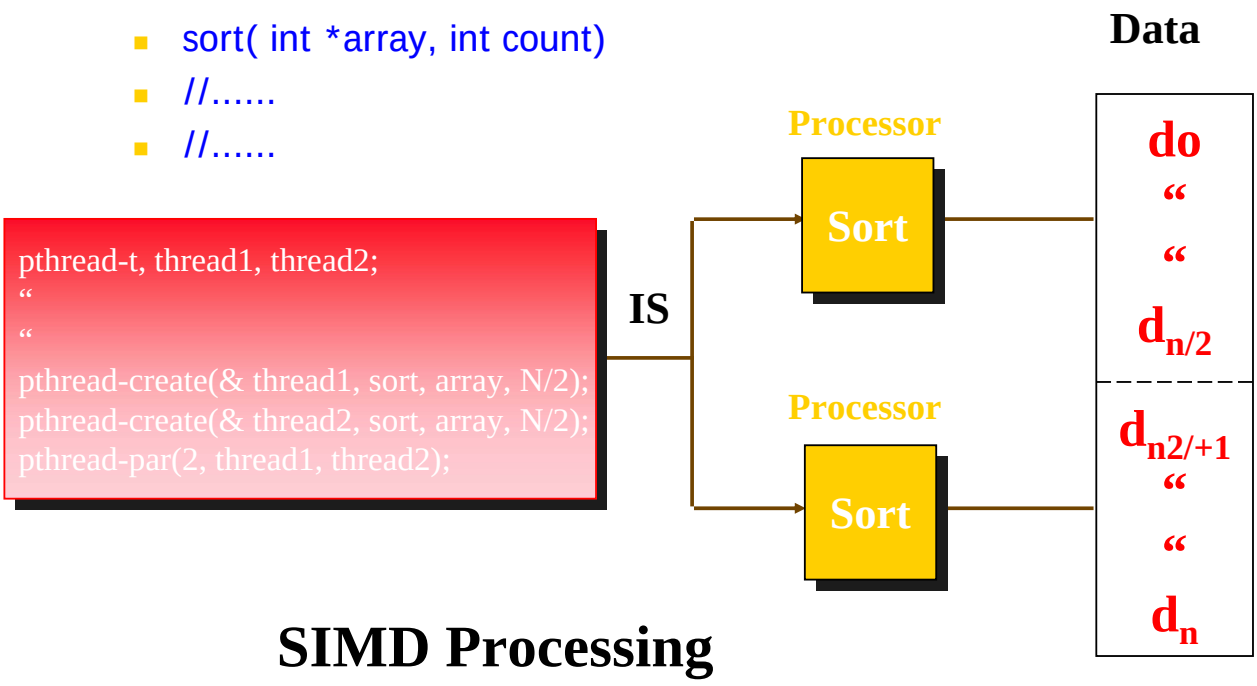
- int add (int a, int b, int & result)
- // function stuff
- int sub(int a, int b, int & result)
- // function stuff



MISD and MIMD Processing

Data Parallelism

- sort(int *array, int count)
- //.....
- //.....



SIMD Processing

Thread Priority

- In Java, each thread is assigned priority, which affects the order in which it is scheduled for running. The threads so far had same default priority (NORM_PRIORITY) and they are served using FCFS policy.
  - Java allows users to change priority:
    - ThreadName.setPriority(intNumber)
      - MIN_PRIORITY = 1
      - NORM_PRIORITY=5
      - MAX_PRIORITY=10

Thread Priority Example

```
class A extends Thread
{
      public void run()
        {
            System.out.println("Thread A started");
            for(int i=1;i<=4;i++)
              {
                  System.out.println("\t From ThreadA: i= "+i);
              }
               System.out.println("Exit from A");
        }
}

class B extends Thread
{
      public void run()
        {
            System.out.println("Thread B started");
            for(int j=1;j<=4;j++)
              {
                  System.out.println("\t From ThreadB: j= "+j);
              }
               System.out.println("Exit from B");
        }
}
```


Thread Priority Example

```
class C extends Thread
{
      public void run()
        {
            System.out.println("Thread C started");
            for(int k=1;k<=4;k++)
              {
                  System.out.println("\t From ThreadC: k= "+k);
              }
               System.out.println("Exit from C");
      }
}

class ThreadPriority
{
       public static void main(String args[])
        {
                  A threadA=new A();
                  B threadB=new B();
                  C threadC=new C();
                threadC.setPriority(Thread.MAX_PRIORITY);
                threadB.setPriority(threadA.getPriority()+1);
                threadA.setPriority(Thread.MIN_PRIORITY);
                System.out.println("Started Thread A");
                 threadA.start();
                System.out.println("Started Thread B");
                 threadB.start();
                System.out.println("Started Thread C");
                 threadC.start();
                 System.out.println("End of main thread");
        }
}
```

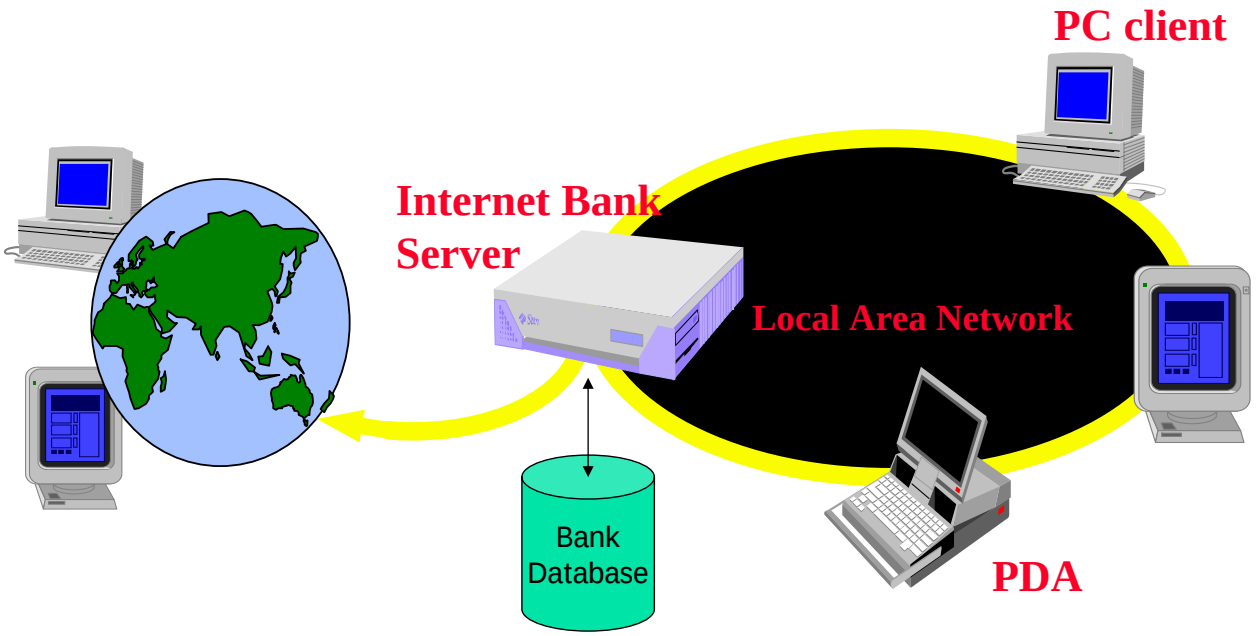
Results

```
Started Thread A
Started Thread B
Started Thread C
Thread B started
End of main thread
Thread C started
    From ThreadC: k= 1
    From ThreadC: k= 2
    From ThreadC: k= 3
    From ThreadC: k= 4
Exit from C
    From ThreadB: j= 1
    From ThreadB: j= 2
    From ThreadB: j= 3
    From ThreadB: j= 4
Exit from B
Thread A started
    From ThreadA: i= 1
    From ThreadA: i= 2
    From ThreadA: i= 3
    From ThreadA: i= 4
Exit from A
```

Accessing Shared Resources

- Applications Access to Shared Resources need to be coordinated.
  - Printer (two person jobs cannot be printed at the same time)
  - Simultaneous operations on your bank account.
  - Can the following operations be done at the same time on the same account?
    - Deposit()
    - Withdraw()
    - Enquire()

Online Bank: Serving Many Customers and Operations



Shared Resources

- If one thread tries to read the data and other thread tries to update the same data, it leads to inconsistent state.
- This can be prevented by synchronising access to the data.
- Use “Synchronized” method:

```
public synchronized void update()
{
        ...
}
```

the driver: 3rd Threads sharing the same object

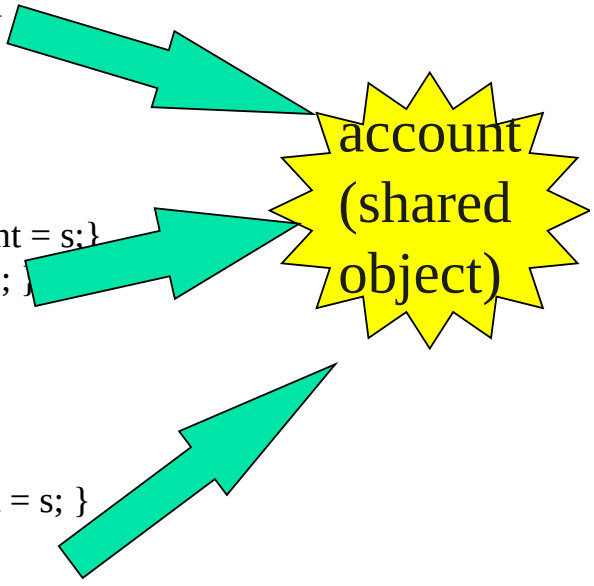
```
class InternetBankingSystem {
      public static void main(String [] args  ) {
          Account accountObject = new Account ();
          Thread t1 = new Thread(new MyThread(accountObject));
          Thread t2 = new Thread(new YourThread(accountObject));
          Thread t3 = new Thread(new HerThread(accountObject));
          t1.start();
          t2.start();
          t3.start();
        // DO some other operation
      } // end main()
}
```


Shared account object between 3 threads

```
class MyThread implements Runnable  {
 Account account;
      public MyThread (Account s) {  account = s;}
      public void run() { account.deposit(); }
} // end class MyThread

class YourThread implements Runnable  {
 Account account;
      public YourThread (Account s) { account = s;}
      public void run() { account.withdraw(); }
} // end class YourThread

class HerThread implements Runnable  {
 Account account;
      public HerThread (Account s) { account = s; }
      public void run() {account.enquire(); }
} // end class HerThread
```



Monitor (shared object access): serializes operation on shared object

```
class Account {    // the 'monitor'
   int balance;

      // if 'synchronized' is removed, the outcome is unpredictable
       public synchronized void deposit( ) {
          // METHOD BODY : balance += deposit_amount;
        }

        public synchronized void withdraw( ) {
          // METHOD BODY: balance -= deposit_amount;
        }
        public synchronized void enquire( ) {
          // METHOD BODY: display balance.
        }
}
```


Producer and Consumer Problem

- Classical multithread synchronization problem
  - two threads, the producer and the consumer, who share a common, fixed-size buffer.
- The producer's job is to generate a piece of data and put it into the buffer.
- The consumer is consuming the data from the same buffer simultaneously.
- The problem is
  - to make sure that the producer will not try to add data into the buffer if it is full
  - that the consumer will not try to remove data from an empty buffer.

Producer and Consumer Problem

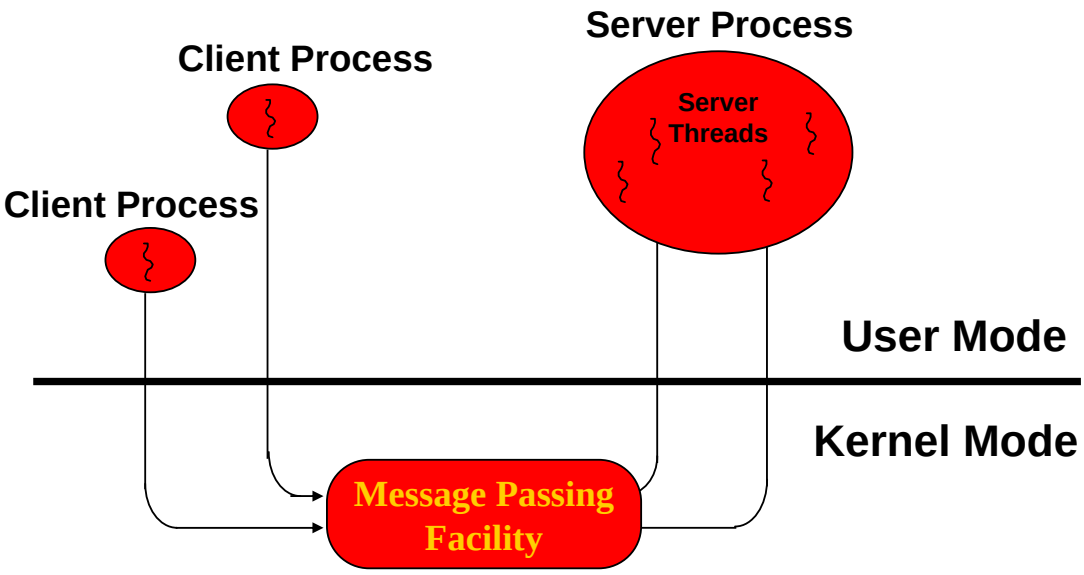
- The solution for this problem involves two parts.
  - The producer should wait when it tries to put the newly created product into the buffer until there is at least one free slot in the buffer.
  - The consumer, on the other hand, should stop consuming if the buffer is empty.

Producer and Consumer Problem

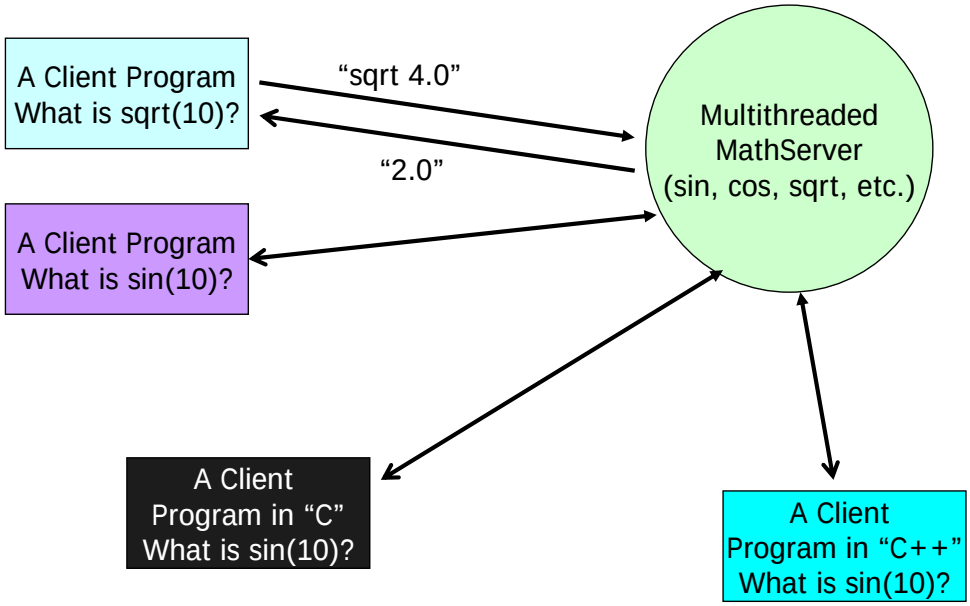
- Code

  Section 14.9.2 – page 382

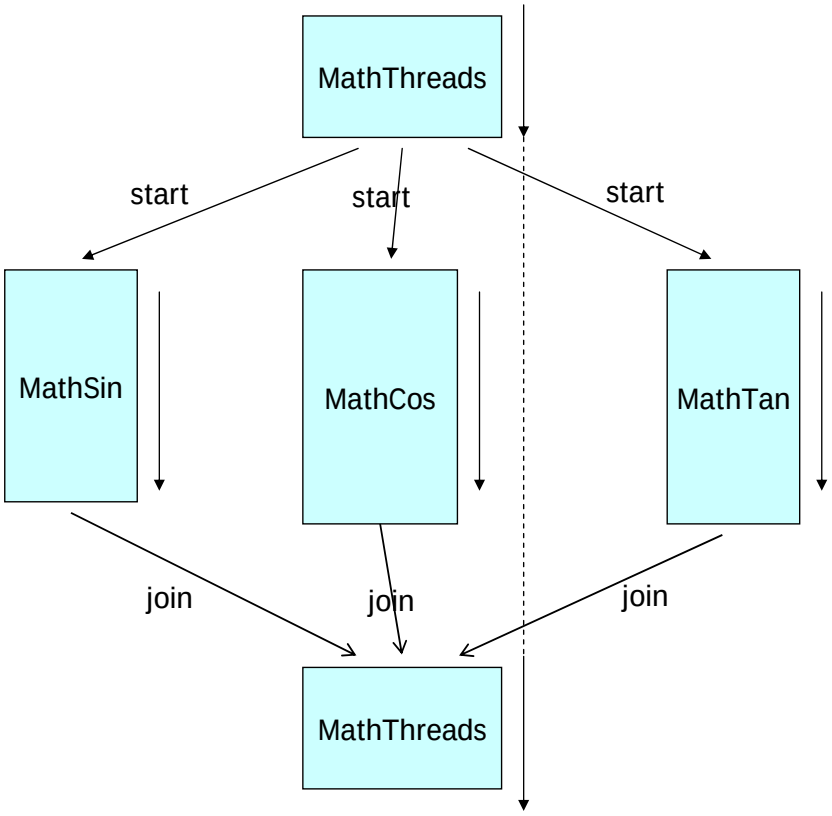
Multithreaded Server



Assignment 1: Multithreaded MathServer – Demonstrates the use of Sockets and Threads



A Multithreaded Program



$$p = \sin(x) + \cos(y) + \tan(z)$$

```
/* MathThreads.java: A program with multiple threads performing concurrent
operations. */
import java.lang.Math;
class MathSin extends Thread {
   public double deg;
   public double res;

   public MathSin(int degree) {
     deg = degree;
   }
   public void run() {
            System.out.println("Executing sin of "+deg);
      double Deg2Rad = Math.toRadians(deg);
      res = Math.sin(Deg2Rad);
      System.out.println("Exit from MathSin. Res = "+res);
   }
}
```

```
class MathCos extends Thread {
   public double deg;
   public double res;

   public MathCos(int degree) {
      deg = degree;
   }
   public void run() {
      System.out.println("Executing cos of "+deg);
      double Deg2Rad = Math.toRadians(deg);
      res = Math.cos(Deg2Rad);
      System.out.println("Exit from MathCos. Res = "+res);
   }
}
class MathTan extends Thread {
   public double deg;
   public double res;

   public MathTan(int degree) {
      deg = degree;
   }
   public void run() {
      System.out.println("Executing tan of "+deg);
      double Deg2Rad = Math.toRadians(deg);
      res = Math.tan(Deg2Rad);
      System.out.println("Exit from MathTan. Res = "+res);
   }
}
```

```
 class MathThreads {
    public static void main(String args[]) {
       MathSin st = new MathSin(45);
       MathCos ct = new MathCos(60);
       MathTan tt = new MathTan(30);
       st.start();
       ct.start();
       tt.start();
       try {   // wait for completion of all thread and then sum
         st.join();
         ct.join(); //wait for completion of MathCos object
         tt.join();
         double z = st.res + ct.res + tt.res;
         System.out.println("Sum of sin, cos, tan = "+z);
       }
       catch(InterruptedException IntExp) {
       }
    }
 }
```

```
 Run 1:
 [raj@mundroo] threads [1:111] java MathThreads
 Executing sin of 45.0
 Executing cos of 60.0
 Executing tan of 30.0
Exit from MathSin. Res = 0.7071067811865475
Exit from MathCos. Res = 0.5000000000000001
Exit from MathTan. Res = 0.5773502691896257
Sum of sin, cos, tan = 1.7844570503761732

Run 2:
[raj@mundroo] threads [1:111] java MathThreads
Executing sin of 45.0
Executing tan of 30.0
Executing cos of 60.0
Exit from MathCos. Res = 0.5000000000000001
Exit from MathTan. Res = 0.5773502691896257
Exit from MathSin. Res = 0.7071067811865475
Sum of sin, cos, tan = 1.7844570503761732

Run 3:
[raj@mundroo] threads [1:111] java MathThreads
Executing cos of 60.0
Executing sin of 45.0
Executing tan of 30.0
Exit from MathCos. Res = 0.5000000000000001
Exit from MathTan. Res = 0.5773502691896257
Exit from MathSin. Res = 0.7071067811865475
Sum of sin, cos, tan = 1.7844570503761732
```

References

- Rajkumar Buyya, Thamarai Selvi, Xingchen Chu, **Mastering OOP with Java**, McGraw Hill (I) Press, New Delhi, India, 2009.
- Sun Java Tutorial – Concurrency:
  - http://java.sun.com/docs/books/tutorial/essential/concurrency/