Threads

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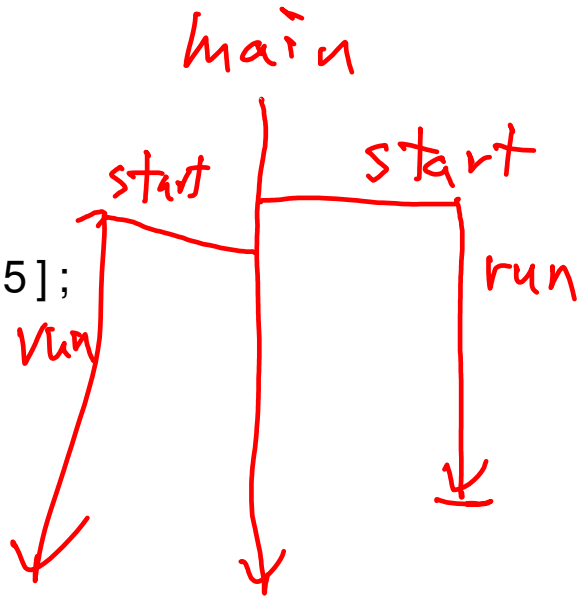
A Basic Example

```
1  class HelloThread extends Thread {
2    int num;
3    HelloThread(int n){ num = n; }
4    public void run() {
5      for(int t = 0; t < 10; t++)
6        System.out.println(t + ": Hello from thread " + num);
7    }
8  }
9
10 public class ThreadDemo1{
11   public static void main(String[] argv){
12     HelloThread[] tarr = new HelloThread[5];
13     for(int i=0;i<5;i++){
14       tarr[i] = new HelloThread(i);
15       tarr[i].start();
16     }
17   }
18 }
```



Another Route: Runnable

```
1  class HelloRunnable implements Runnable {
2    int num;
3    HelloRunnable(int n){ num = n; }
4    public void run() {
5      for(int t = 0; t < 10; t++)
6        System.out.println(t + ": Hello from thread " + num);
7    }
8  }
9
10 public class ThreadDemo2{
11   public static void main(String[] argv){
12     Thread[] tarr = new Thread[5];
13
14     for(int i=0;i<5;i++){
15       HelloRunnable r = new HelloRunnable(i);
16       tarr[i] = new Thread(r);
17       tarr[i].start();
18     }
19   }
20 }
```

Slow Things Down: `sleep`

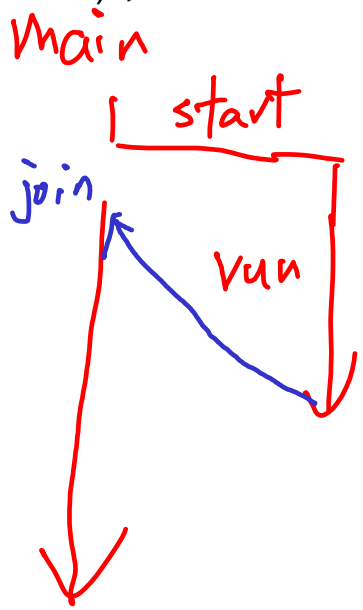
```
1  public class ThreadDemo3{
2    public static void main(String[] argv)
3      throws InterruptedException{
4
5      for(int i=0;i<10;i++){
6        System.out.println(i);
7        Thread.sleep(1000);
8      }
9    }
10 }
```

Wake Up: interrupt

```
1  class HelloThread extends Thread {
2    int num;  Thread tr;
3    HelloThread(int n, Thread _tr){ num = n; tr = _tr; }
4    public void run() {
5      for(int t = 0; t < 10; t++){
6        System.out.println(t + ": Hello from thread " + num);
7        tr.interrupt();
8        try{ Thread.sleep(500); }
9        catch(InterruptedException e){
10         System.out.println("the sleep of " + num + " interrupted");
11       }
12     }
13   }
14 }
15 public class ThreadDemo4{
16   public static void main(String[] ar) throws InterruptedException{
17     HelloThread[] tarr = new HelloThread[5];
18     for(int i=0;i<5;i++){
19       tarr[i] = new HelloThread(i,
20         (i == 0? Thread.currentThread() : tarr[i-1]));
21       tarr[i].start();
22     }
23   }
```

Wait for Finish: `join`

```
1  class HelloThread extends Thread {
2    int num;
3    HelloThread(int n){ num = n; }
4    public void run() {
5      for(int t = 0; t < 10; t++){
6        System.out.println(t + ": Hello from thread " + num);
7      }
8    }
9  }
10
11 public class ThreadDemo5{
12   public static void main(String[] argv) throws
         InterruptedException{
13     for(int i=0;i<3;i++){
14       System.out.println("Starting a new thread");
15       HelloThread t = new HelloThread(i);
16       t.start();
17       t.join();
18     }
19   }
20 }
```



Story of a Bank: Part I

Once upon a time, a bank uses the following system to allow customers to spend in local stores easily

```
1       localcredit = getCredit(customer);
2       tospend = getPrice(item);
3       if (tospend <= localcredit){
4         newcredit = localcredit - tospend;
5         notifyNewCredit(newcredit);
6       }
```

Story of a Bank: Part II

Normally,

```
1        localcredit1 = getCredit(customer1); //10000
2        tospend1 = getPrice(item1); //3000
3        if (tospend1 <= localcredit1){
4          newcredit1 = localcredit1 - tospend1; //2000 7000
5          notifyNewCredit(newcredit1);
6        }
7        localcredit2 = getCredit(customer2); //10000
8        tospend2 = getPrice(item2); //2000
9        if (tospend2 <= localcredit2){
10         newcredit2 = localcredit2 - tospend2; //8000
11         notifyNewCredit(newcredit2);
12       }
```

Story of a Bank: Part III

Unfortunately, customer 1 and 2 share the same account but go to different stores

```
1   localcredit1 = getCredit(customer1); //10000
2   localcredit2 = getCredit(customer2); //10000
3   tospend1 = getPrice(item1); //3000
4   if (tospend1 <= localcredit1){
5     newcredit1 = localcredit1 - tospend1; //7000
6     notifyNewCredit(newcredit1);
7   }
8   tospend2 = getPrice(item2); //2000
9   if (tospend2 <= localcredit2){
10    newcredit2 = localcredit2 - tospend2; //8000
11    notifyNewCredit(newcredit2);
12  }
13  getCredit(customer1); //8000
14  getCredit(customer2); //~~7000~~ 8000
```

Story of a Bank: The End

Local copies are not trustworthy. Must update global copy **atomically**

An Example with Counter Threads I

```
1  class Counter{
2      private int c = 0;
3      private int ic, dc;
4      private void sleep(){
5          try{ Thread.sleep(200); }
6          catch(Exception e){ System.err.println(e); }
7      }
8
9      public void inc(){ ic++; sleep();
10         int newc = c + 1; sleep(); c = newc;}
11     public void dec(){ dc++; sleep();
12         int newc = c - 1; sleep(); c = newc;}
13     public void info(){
14         System.out.println(ic + " - " + dc + " = " + c);
15     }
16 }
17
18
19
20
21
```

An Example with Counter Threads II

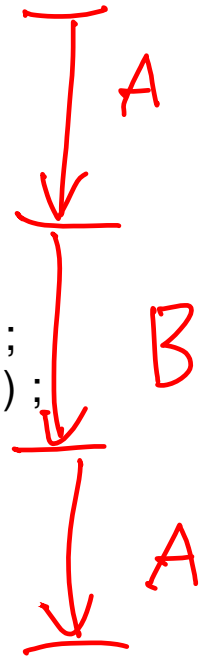
```
22 class IncCounterThread extends Thread{
23     Counter c;
24     IncCounterThread(Counter c){ this.c = c;}
25     public void run(){
26         while(true){
27             //synchronized(c){
28             {
29                 c.inc();
30                 c.info();
31             }
32             try{
33                 Thread.sleep(100);
34             }
35             catch(Exception e){
36             }
37         }
38     }
39 }
40
41
42
43
```

An Example with Counter Threads III

```
44 class DecCounterThread extends Thread{
45     Counter c;
46     DecCounterThread(Counter c){ this.c = c;}
47     public void run(){
48         while(true){
49             //synchronized(c){
50             {
51                 c.dec();
52                 c.info();
53             }
54             try{
55                 Thread.sleep(100);
56             }
57             catch(Exception e){
58             }
59         }
60     }
61 }
62
63
64
65
```

An Example with Counter Threads IV

```
66 public class CounterDemo{
67     public static void main(String[] argv){
68         Counter c = new Counter();
69         IncCounterThread plus = new IncCounterThread(c);
70         DecCounterThread minus = new DecCounterThread(c);
71
72         plus.start();
73         minus.start();
74     }
75 }
```



ic++; //1
dc++; //1
newc = c-1; //-1
c = newc; //-1
newc = c+1; //1
c = newc; //1

Story of a Couple: Part I

Once upon a time, a couple shares a credit card account. To prevent overdraft, they agreed on the following protocol for using the credit card:

```
1        tospend = getPrice(item);
2        currentlimit = checkCreditbyCellphone();
3        if (tospend <= currentlimit)
4          do_transaction(); //atomically
```

Story of a Couple: Part II

Normally,

```
1        tospend = getPrice(item); //by George: 50000
2        currentlimit = checkCreditbyCellphone(); //60000
3        if (tospend <= currentlimit) //by Mary: yes
4          do_transaction(); //atomically
5        tospend = getPrice(item); //by Mary: 20000
6        currentlimit = checkCreditbyCellphone(); //10000
7        if (tospend <= currentlimit) //by Mary: no
8          do_transaction(); //atomically
```

Story of a Couple: Part III

Unfortunately,

```
1        tospend = getPrice(item); //by George: 50000
2        currentlimit = checkCreditbyCellphone(); //60000
3        //George drives to the store
4        tospend = getPrice(item); //by Mary: 20000
5        currentlimit = checkCreditbyCellphone(); //60000
6        if (tospend <= currentlimit) //by Mary: yes
7          do_transaction();
8        if (tospend <= currentlimit) //by George: yes
9          do_transaction(); //OVERDRAFT!!
```

Story of a Couple: The End

Spent should happen **immediately** after checking

An Example with Couple Threads I

```
1  class NegativeException extends Exception{
2      NegativeException(double value){
3          super("Negative value " + value + " not allowed.");
4      }
5  }
6
7  class CreditCard{
8      int credit = 60000;
9
10     public int getcredit(){ return credit; }
11     public synchronized void spend(int amount) throws
           NegativeException{
12         int newcredit = credit - amount;
13         credit = newcredit;
14
15         if (credit < 0)
16             throw new NegativeException(credit);
17     }
18 }
19             synchronized(this){
20
               ...
               }
```

An Example with Couple Threads II

```
21 class Person extends Thread{
22     int tospend;
23     CreditCard c;
24     Person(int tospend, CreditCard c){ this.tospend = tospend;
           this.c = c;}
25     void spend() throws NegativeException, InterruptedException{
26         synchronized(c){
27             int credit = c.getcredit();
28             Thread.sleep(100);
29             if (credit >= tospend){
30                 c.spend(tospend);
31             }
32         }
33     }
34     synchronized void spend_wrong() throws NegativeException,
           InterruptedException{
35             int credit = c.getcredit();
36             Thread.sleep(100);
37             if (credit >= tospend){
38                 c.spend(tospend);
39             }
40     }
```

synchronized(this){

}

An Example with Couple Threads III

```
41
42      void spend_wrong_equiv() throws NegativeException,
            InterruptedException{
43          synchronized(this){
44              int credit = c.getcredit();
45              Thread.sleep(100);
46              if (credit >= tospend){
47                  c.spend(tospend);
48              }
49          }
50      }
51
52      public void run(){
53          try{
54              spend();
55          }
56          catch(Exception e){
57              System.out.println(e);
58          }
59      }
60  }
61
```

An Example with Couple Threads IV

```
62 public class CreditCardDemo{
63     public static void main(String[] argv){
64         for(int i = 0; i < Integer.parseInt(argv[0]); i++){
65             CreditCard c = new CreditCard();
66             Person George = new Person(50000, c);
67             Person Mary = new Person(20000, c);
68
69             George.start();
70             Mary.start();
71         }
72     }
73 }
```

Synchronization

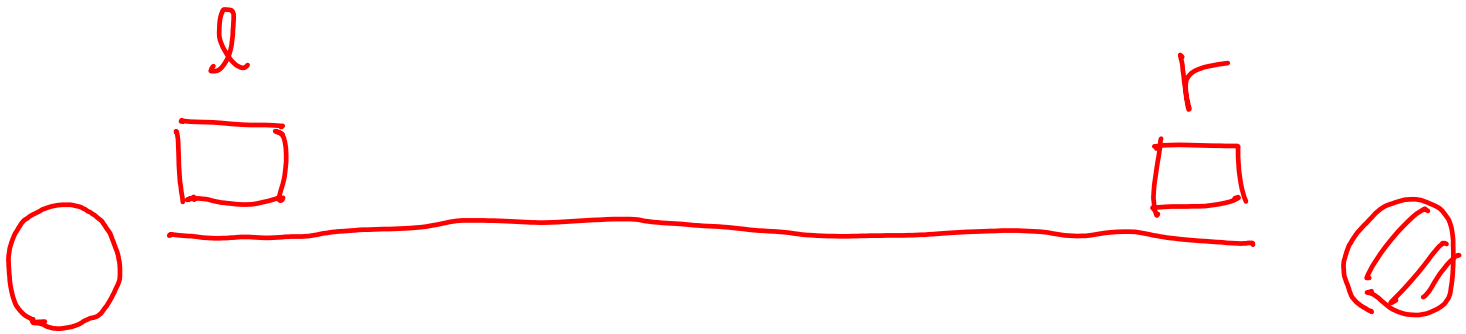
`synchronized`: binds operations altogether (with respect to a lock)

- synchronized method: the lock is the class (for static method) or the object (for non-static method)
  - usually used to protect the variables within the class/object
- synchronized block: the lock is explicitly provided
  - flexible, fine-grained use

More on the Lock

- after getting the lock, can “use” any synchronized method/block that depends on the lock
- lock releases after the method/block finishes (by return or exception)

A Story of the Black and White Goats: Deadlock




```
synchronized(l){
  synchronized(r){
    gogogo();
  }
}
```

```
synchronized(r){
  synchronized(l){
    gogogo_black();
  }
}
```