CS1110 10 March 2009
While loops

Reading: today: Ch. 7 and ProgramLive sections.

For next time: Ch. 8.1-8.3

Prelim in two days: Th 7:30-9pm Uris Aud. (G01)
A5 due in one day: Wed 11:59pm

Two handouts for today; keep them both out.

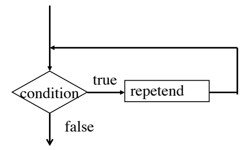
1

Beyond ranges of integers: the while loop

```
while (<condition>) {
  sequence of declarations
  and statements
}
```

<condition>: a boolean expression.

<repetend>: sequence of statements.



In comparison to for-loops: we get a broader notion of "there's still stuff to do" (not tied to integer ranges), but *we* must ensure that "condition" stops holding (since there's no explicit increment).

2

Canonical while loops

```
// simulate for (int k= b; k <= c; k= k+1)
int k= b;
while (k <= c) {
    Process k;
    k= k+1;
}
```

```
// process a sequence of input not of fixed size
<initialization>;
while (<still input left>) {
    Process next piece of input;
    make ready for the next piece of input;
}
```

3

Interesting while loops (why are the invariants missing?)

```
// Von Neumann's "fair coin" from
//    unfair coin
// heads/tails is true/false
public static boolean fairFlip() {
    while (true) {
        f1= new unfair flip;
        f2= new unfair flip;
        if (f1 && !f2) {
            return true;
        }
        if (!f1 && f2) {
            return false;
        }
    }
}
```

```
// open q. in mathematics
public static boolean collatz(int n) {
    while (n != 1) {
        if (n%2 == 0) {
            n= n/2;
        }
        else {
            n= 3*n +1;
        }
    }
    return true;
}
```

4

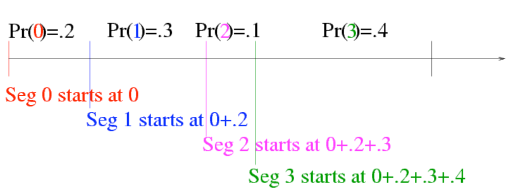
A weighted die - extremely useful for scientific simulations

double r= Math.random() draws r uniformly at random from [0,1).

Problem: use this to produce an int in 0..n-1 given (non-zero, correct) probs Pr(i) for i in 0..n-1.

Idea: the Pr(i) divide [0,1) into segments proportional to Pr(i).

So, loop through the segments to find the one containing r.



5

The while loop: 4 loopy questions. Allows us to focus on one thing at a time and thus separate our concerns.

```
// Set c to the number of 'e's in String s.
int n= s.length();
c= 0;  k= 0;
//  inv: c = #. of 'e's in s[0..k-1]
while (k < n) {
   if (s.charAt(k) == 'e')
         c= c + 1;
   k= k+ 1;
}
// c = number of 'e's in s[0..n-1]
```

1. How does it start? (what is the initialization?)

2. When does it stop? (From the invariant and the falsity of loop condition, deduce that result holds.)

3. (How) does it make progress toward termination?

4. How does repetend keep invariant true?

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Suppose we are thinking of this while loop:

```
initialization;
while ( B ) {
    repetend
}
```

We add the postcondition and also show where the invariant must be true:

```
initialization;
// invariant: P
while ( B ) {
   // { P and B}
   repetend
   // { P }
}
// { P and !B }
// { Result R }
```

The four loopy questions

Second box helps us develop four loopy questions for developing or understanding a loop:

1. How does loop start? Initialization must truthify inv P.

2. When does loop stop?

At end, P and !B are true, and these must imply R. Find !B that satisfies P && !B => R.

3. Make progress toward termination? Put something in repetend to ensure this.

4. How to keep invariant true? Put something in repetend to ensure this.

7

Understanding assertions about lists

```
   0 1 2 3 4 5 6 7 8
v  X Y Z X A C Z Z Z
```

This is a list of Characters

```
   0   3   k      8
v  ≥ C | ? | all Z's        k  6
```

This is an assertion about v and k. It is **true** because chars of v[0..3] are greater than 'C' and chars of v[6..8] are 'Z's.

```
   0   3   k      8
v  ≥ C | ? | all Z's        k  5

   0       k      8
v  ≥ C   | all Z's          k  6

   0     k        8
v  ≥ W | A | C | all Z's    k  4
```

Indicate whether each of these 3 assertions is true or false.

8

Appendix examples: Develop loop to store in x the sum of 1..100.

We'll keep this definition of x and k true:
x = sum of 1..k–1

1. How should the loop start? Make range 1..k–1 empty: **k= 1; x= 0;**

2. When can loop stop? What condition lets us know that x has desired result? When **k == 101**

3. How can repetend make progress toward termination? **k= k+1;**

4. How do we keep def of x and k true? **x= x + k;**

Four loopy questions

```
k= 1;  x= 0;
// invariant: x = sum of 1..(k–1)
while ( k != 101) {
    x= x + k;
    k= k + 1;
}
// { x = sum of 1..100 }
```

9

Roach infestation

```
/** = number of weeks it takes roaches to fill the apartment --see p 244 of text*/
public static int roaches() {
    double roachVol= .001;    // Space one roach takes
    double aptVol= 20*20*8;  // Apartment volume
    double growthRate= 1.25; // Population growth rate per week

    int w= 0;       // number of weeks
    int pop= 100; // roach population after w weeks

    // inv: pop = roach population after w weeks   AND
    //        before week w, volume of the roaches < aptVol
    while (aptVol > pop * roachVol ) {
        pop= (int) (pop * growthRate);
        w= w + 1;
    }
    return w;
}
```

10

Iterative version of logarithmic algorithm to calculate b**c
(we've seen a recursive version before).

```
/** set z to b**c, given c ≥ 0 */
int x= b; int y= c; int z= 1;
// invariant:  z * x**y = b**c  and 0 ≤ y ≤ c
while (y != 0) {
    if (y % 2 == 0)
          { x= x * x; y= y/2;  }
    else { z= z * x; y= y – 1; }
}
// { z = b**c }
```

11

Calculate quotient and remainder when dividing x by y

x/y = q + r/y   **21/4= 4 + 3/4**

Property: x = q * y + r and 0 ≤ r < y

```
/** Set q to quotient  and r to remainder.
    Note: x >= 0 and y > 0 */
int q= 0; int r= x;
// invariant:  x = q * y + r    and 0 ≤ r
while (r >= y) {
        r= r – y;
        q= q + 1;
}
// { x = q * y + r    and   0 ≤ r < y }
```

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