BBM 101 – Introduction to Programming I

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Today

- **Iteration Control**
  - Loop Statements
    - **for**, **while**, **do-while** structures
  - **break** and **continue**
  - Some simple numerical programs

Loop Statements

- Loop is a group of instructions computer executes repeatedly while some condition remains true

- Counter-controlled Repetition
  - Definite repetition: know how many times loop will execute
  - Control variable used to count repetitions

- Sentinel-controlled Repetition
  - Indefinite repetition
  - Used when number of repetitions not known
  - Sentinel value indicates "end of data"

The for Loop

- Syntax

```
for (initialization; condition; modify)
        statement;
```

- The program will keep executing the *statement* inside the **for** as long as the condition is true (non zero)

- The *condition* is tested ***before*** each iteration of the loop. The loop terminates when the condition is false.

- The loop is controlled by a variable which is initialized and modified by the *initialization* and *modify* (e.g. increment operation) expressions, respectively.

The for Loop (Example)

- Find the sum of numbers between 1 and 100

```
int sum = 0;
for (i = 0; i <= 100; i++) {
        sum = sum + i;
}
```

control variable *i* = initial value 0

increment of control variable *i*

loop continuation condition
(100 is the final value of *i* for which the condition is true)

The for Loop (Further Examples)

- Loop from 100 to 1 in increments of -1

```
for (i = 100; i >= 1; i--)
```

value of i when the loop terminates is 0.

- Loop from 7 to 77 in increments of 7

```
for (i = 7; i <= 77; i+7)
```

value of i when the loop terminates is 84.

Example: A program that prints the sum of even numbers between 0 and 100

```
/*Summation with for */
#include <stdio.h>

int main()
{
    int sum = 0, number;
    for ( number = 2; number <= 100; number += 2 ){
        sum += number;
    }
    printf( "Sum is %d\n", sum );
    return 0;
}
```

```
Sum is 2550
```

The while Loop

- Syntax

```
while (condition)
        statement;
```

- The program will repeatedly execute the *statement* inside the **while** as long as the condition is true (non zero)

- The *condition* is tested ***before*** each iteration of the loop. The loop terminates when the condition is false.

- If the condition is initially false (0), the statement will not be executed.

The while Loop (Example)

- Find the sum of numbers between 1 and 100

```
int sum = 0, i = 1;
while (i <= 100) {
        sum = sum + i;
        i = i + 1;
}
```

Counter Controlled Repetition (Example)

- *A class of 10 students* took a quiz. The grades (integers in the range 0 to 100) for this quiz are available to you. Determine the class average on the quiz.

- The algorithm
  1. *Set total to zero*
  2. *Set grade counter to one*
  3. *While grade counter is less than or equal to 10*
     Input the next grade
     Add the grade to the total
     Add one to the grade counter
  4. *Set the class average to the total divided by ten*
  5. *Print the class average*

```c
/* Class average program with counter-controlled repetition */
#include <stdio.h>

int main()
{
        int counter, grade, total, average;

        /* initialization phase */
        total = 0;
        counter = 1;

        /* processing phase */
        while ( counter <= 10 ) {
                printf( "Enter grade: " );
                scanf( "%d", &grade );
                total = total + grade;
                counter = counter + 1;
        }

        /* termination phase */
        average = total / 10.0;
        printf( "Class average is %d\n", average );

        return 0;   /* indicate program ended successfully */
}
```

```
Enter grade: 98
Enter grade: 76
Enter grade: 71
Enter grade: 87
Enter grade: 83
Enter grade: 90
Enter grade: 57
Enter grade: 79
Enter grade: 82
Enter grade: 94
Class average is 81
```

Sentinel Controlled Repetition (Example)

- Revisiting the class average problem: *Arbitrary number of students* took the quiz this time.
  - i.e., number of students will not be known when the program runs
  - How is the program going to know when to end?

- Use sentinel value
  - Also called *signal value*, *dummy value*, or *flag value*
  - Indicates *end of processing*
  - Loop ends when user inputs the sentinel value
  - Sentinel value is chosen in a way that it cannot be confused with a regular input

```c
/* Class average program with sentinel-controlled repetition */
#include <stdio.h>
int main()
{
        float average;
        int counter, grade, total;

        /* initialization phase */
        total = 0;
        counter = 0;

        /* processing phase */
        printf( "Enter grade, -1 to end: " );
        scanf( "%d", &grade );
        while ( grade != -1 ) {
                total = total + grade;
                counter = counter + 1;
                printf( "Enter grade, -1 to end: " );
                scanf( "%d", &grade );
        }

        /* termination phase */
        if( counter != 0 ) {
                average = ( float ) total / counter;
                printf( "Class average is %.2f", average );
        } else
           printf( "No grades were entered\n" );

        return 0;   /* indicate program ended successfully */
}
```

```
Enter grade, -1 to end: 75
Enter grade, -1 to end: 94
Enter grade, -1 to end: 97
Enter grade, -1 to end: 88
Enter grade, -1 to end: 70
Enter grade, -1 to end: 64
Enter grade, -1 to end: 83
Enter grade, -1 to end: 89
Enter grade, -1 to end: -1
  Class average is 82.50
```

The do-while Loop

- Syntax

```
do {
        statement;
} while (condition)
```

- The program will definitely execute the statement at least once and then repeatedly keep executing the *statement* inside the **do-while** as long as the condition is true (non zero)

- The *condition* is tested ***after*** each iteration of the loop. The loop terminates when the condition is false.

- If the condition is initially false (0), the statement will be executed anyways.

The do-while Loop (Example)

- Find the sum of numbers between 1 and 100

```
int sum = 0, i = 1;
do {
        sum = sum + i;
        i = i + 1;
} while (i <= 100)
```

Which example better suites for the use of do-while loop?

- Try until the user enters a valid number

```
int number;
do {
        printf("Enter a number from 0 to 100: ");
        scanf("%d", &number);
} while (number >= 0 && number <= 100)
```

Nesting Control Structures

- Problem
  - A college has a list of test results (1 = pass, 2 = fail) for 10 students
  - Write a program that counts the number of passed and failed students

- Notice that
  - The program must process 10 test results
    - Counter-controlled loop will be used
  - Two counters can be used
    - One for number of passes, one for number of fails
  - Each test result is a number—either a 1 or a 2
    - If the number is not a 1, we assume that it is a 2

Nesting while loop and if structure

```
#include <stdio.h>
int main()
{
       int passes = 0, failures = 0, student = 1, result;

       while(student <= 10){

              printf( "Enter result: 1(Pass), 2(Fail): " );
              scanf( "%d", &result);

              if(result == 1)
                 passes++;
              else
                 failures++;

              student = student + 1;
       }

       printf("Passed: %d Failed: %d\n", passes, failures);

       return 0;
}
```

Nesting while loop and switch structure

```
#include <stdio.h>

int main()
{
        char grade;
        int aCount=0, bCount=0, cCount=0, dCount=0, fCount=0 ;

        printf( "Enter the letter grades. Enter X to exit. \n" );

        while((grade = getchar()) != 'X') {

                switch ( grade ) {
                   case 'A': case 'a': ++aCount; break;
                   case 'B': case 'b': ++bCount; break;
                   case 'C': case 'c': ++cCount; break;
                   case 'D': case 'd': ++dCount; break;
                   case 'F': case 'f': ++fCount; break;
                   default:printf( "Incorrect letter grade entered." );
                           printf( "Enter a new grade.\n" );
                           break;}
        }
}
```

Nested Loops

- When a loop body includes another loop construct this is called a *nested loop*.

- In a nested loop structure the inner loop is executed from the beginning every time the body of the outer loop is executed.

```
value = 0;
for (i=1; i<=10; i=i+1)
        for (j=1; j<=5; j=j+1)
                value = value + 1;
```

- How many times the inner loop is executed? → **50 times**

Nested Loops (Example)

- How many times the inner loop is executed?

```
for (i=1; i<=5; i=i+1){
        for (j=1; j<=i; j=j+1)
                printf("*");
        printf("\n");
}
```

i	j
1	1
2	1, 2
3	1, 2, 3
4	1, 2, 3, 4
5	1, 2, 3, 4, 5

→ 15 times

Output

```
*
**
***
****
*****
```

Nesting while and for Loops

```
int main()
{
   int num, count, total = 0;

   printf("Enter a value or a negative number to end: " );
   scanf("%d", &num );

   while( num >= 0 ) {
       for (count = 1; count <= num; count++)
              total = total + count;

       printf("%d %d",num, total);
       printf( "Enter a value or a negative number to end:");
       scanf( "%d", &num );
       total = 0;
   }
   return 0;
}
```

This program reads numbers until the user enters a negative number. For each number read, it prints the number and the summation of all values between 1 and the given number.

The break Statement

- Causes immediate exit from a *while, for, do…while* or switch statement

- Program execution continues with the first statement after the containing block

- Common uses of the break statement
  - Escape early from a loop
  - Skip the remainder of a switch statement

The break Statement (Example)

```
#include <stdio.h>

int main(){
        int x;

        for (x = 1; x <= 10 ; x++) {
                if ( x == 5 )
                        break;
                printf("%d ", x);
        }

        printf("\nBroke out of the loop at x =%d ", x);
        return 0;
}
```

```
1 2 3 4
Broke out of the loop at x = 5
```

The continue Statement

- Skips the remaining statements in the body of a *while, for* or *do…while* statement
  - Proceeds with the next iteration of the loop

- *while* and *do…while* loops
  - Loop-continuation test is evaluated immediately after the continue statement is executed

- *For* loop
  - Increment expression is executed, then the loop-continuation test is evaluated

The continue Statement (Example)

```
#include <stdio.h>

int main(){
        int x;

        for (x = 1; x <= 10 ; x++) {
                if ( x == 5 )
                        continue;
                printf("%d ", x);
        }

        printf("\nUsed continue to skip printing the value 5");
        return 0;
}
```

```
1 2 3 4 6 7 8 9 10
Used continue to skip printing the value 5
```

Exhaustive Enumeration

```
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
int main() {
  int x, ans;
  printf("Enter an integer: ");
  scanf("%d", &x);
  ans = 0;
  while (pow(ans,3)<abs(x))
          ans++;
  if (pow(ans,3)!=abs(x))
        printf("%d is not a perfect cube\n", x);
  else {
        if (x<0) ans = -ans;
        printf("Cube root of %d is %d\n", x, ans);
  }
  return 0;
}
```

This program finds the cube root of a perfect cube using a variant of ***guess and check*** *technique called* ***exhaustive enumeration****.*

- *Enumerate all possibilities until we get the right answer or exhaust the space of possibilities.*

Approximate Solutions

- Suppose we want to find the square root of any non-negative number?
- Can't guarantee exact answer, but just look for something close enough
- Start with exhaustive enumeration
  - Take small steps to generate guesses in order
  - Check to see if close enough

Slide credit: E. Grimson, J. Guttag and C. Terman

Square root of any non-negative number

```
int x = 25;
double epsilon = 0.01;
double step = epsilon*epsilon;
int numGuesses = 0;
double ans = 0.0;
while (fabs(ans*ans - x) >= epsilon && ans <= x) {
        ans += step;
        numGuesses++;
}
printf("numGuesses = %d\n", numGuesses);
if (fabs(ans*ans - x) >= epsilon)
    printf("Failed on square root of %d", x);
else
    printf("%.3lf is close to square root of %d", ans, x);
```

```
numGuesses = 49990
4.999 is close to square root of 25
```

Square root of any non-negative number

```
int x = 25;
double epsilon = 0.01;
double step = epsilon*epsilon;
int numGuesses = 0;
double ans = 0.0;
while (fabs(ans*ans - x) >= epsilon && ans <= x) {
        ans += step;
        numGuesses++;
}
printf("numGuesses = %d\n", numGuesses);
if (fabs(ans*ans - x) >= epsilon)
    printf("Failed on square root of %d", x);
else
    printf("%.3lf is close to square root of %d", ans, x);
```

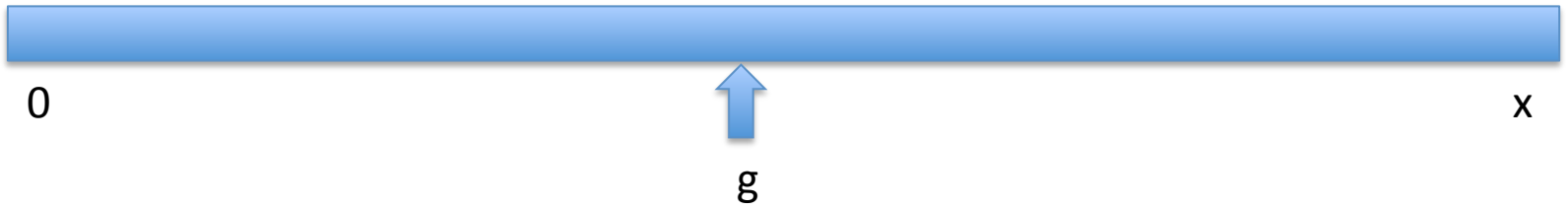
```
numGuesses = 49990
4.999 is close to square root of 25
```

Step could be any small number

- *If too small, takes a long time to find square root*
- *If make too large, might skip over answer without close enough*

Bisection Search

- We know that the square root of x lies between 0 and x, from mathematics
- Rather than exhaustively trying things starting at 0, suppose instead we pick a number in the middle of this range

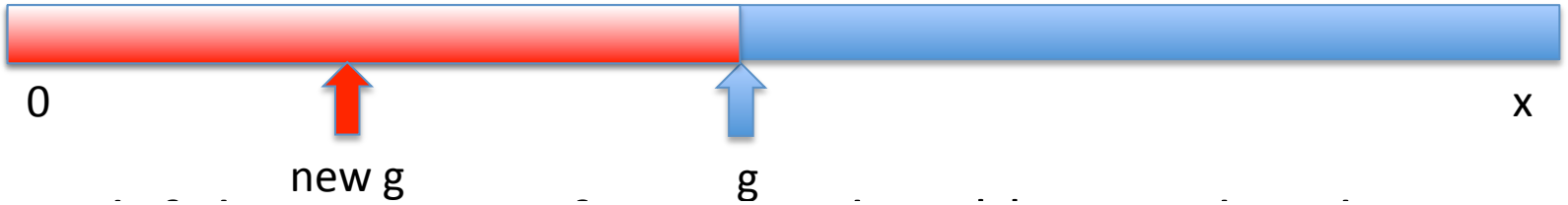


- If we are lucky, this answer is close enough

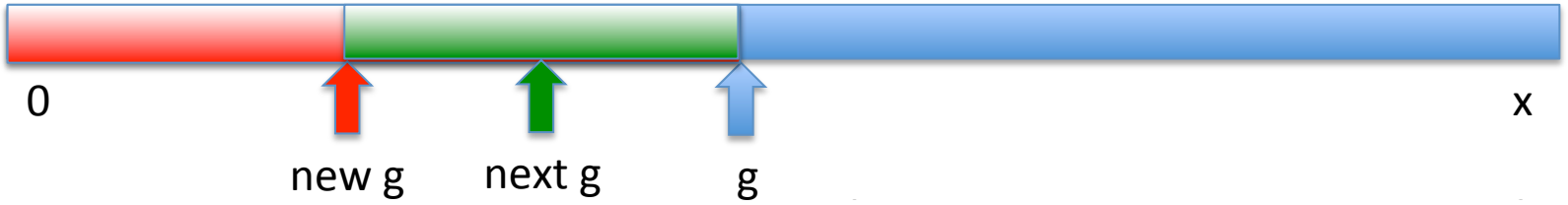
Slide credit: E. Grimson, J. Guttag and C. Terman

Bisection Search

- If not close enough, is guess too big or too small?
- If g**2 > x, then know g is too big; but now search



- And if this new g is, for example, g**2 < x, then know too small; so now search



- At each stage, reduce range of values to search by half

Slide credit: E. Grimson, J. Guttag and C. Terman

Approximating Square Root using Bisection Search

```
int x = 25;
double epsilon = 0.01;
int numGuesses = 0;
double low = 0.0;
double high = MAX(1.0, x);
double ans = (high + low)/2.0;
while (fabs(ans*ans - x) >= epsilon) {
  printf("low = %.5lf high = %.5lf ans = %.5lf\n", low, high, ans);
  numGuesses++;
  if (ans*ans < x)
      low = ans;
  else high = ans;
      ans = (high + low)/2.0;
  }
printf("numGuesses = %d\n", numGuesses);
printf("%.5lf is close to square root of %d", ans, x);
```

Approximating Square Root using Bisection Search

```
int x = 25;
double epsilon = 0.01;
int numGuesses = 0;
double low = 0.0;
double high = MAX(1.0, x);
double ans = (high + low)/
while (fabs(ans*ans - x) >
  printf("low = %.5lf high
  numGuesses++;
  if (ans*ans < x)
      low = ans;
  else high = ans;
      ans = (high + low)/2.0;
  }
printf("numGuesses = %d\n", numGuesses);
printf("%.5lf is close to square root of %d", ans, x);
```

```
low = 0.00000 high = 25.00000 ans = 12.50000
low = 0.00000 high = 12.50000 ans = 6.25000
low = 0.00000 high = 6.25000 ans = 3.12500
low = 3.12500 high = 6.25000 ans = 4.68750
low = 4.68750 high = 6.25000 ans = 5.46875
low = 4.68750 high = 5.46875 ans = 5.07812
low = 4.68750 high = 5.07812 ans = 4.88281
low = 4.88281 high = 5.07812 ans = 4.98047
low = 4.98047 high = 5.07812 ans = 5.02930
low = 4.98047 high = 5.02930 ans = 5.00488
low = 4.98047 high = 5.00488 ans = 4.99268
low = 4.99268 high = 5.00488 ans = 4.99878
low = 4.99878 high = 5.00488 ans = 5.00183
numGuesses = 13
5.00031 is close to square root of 25
```

Approximating Square Root using Bisection Search

```
int x = 25;
double epsilon = 0.01;
int numGuesses = 0;
double low = 0.0;
double high = MAX(1.0, x);
double ans = (high + low)/
while (fabs(ans*ans - x) >
  printf("low = %.5lf high
  numGuesses++;
  if (ans*ans < x)
      low = ans;
  else high = ans;
      ans = (high + low)/2.0;
  }
printf("numGuesses = %d\n", numGuesses);
printf("%.5lf is close to square root of %d", ans, x);
```

```
low = 0.00000 high = 25.00000 ans = 12.50000
low = 0.00000 high = 12.50000 ans = 6.25000
low = 0.00000 high = 6.25000 ans = 3.12500
low = 3.12500 high = 6.25000 ans = 4.68750
low = 4.68750 high = 6.25000 ans = 5.46875
low = 4.68750 high = 5.46875 ans = 5.07812
low = 4.68750 high = 5.07812 ans = 4.88281
low = 4.88281 high = 5.07812 ans = 4.98047
low = 4.98047 high = 5.07812 ans = 5.02930
low = 4.98047 high = 5.02930 ans = 5.00488
low = 4.98047 high = 5.00488 ans = 4.99268
low = 4.99268 high = 5.00488 ans = 4.99878
low = 4.99878 high = 5.00488 ans = 5.00183
numGuesses = 13
5.00031 is close to square root of 25
```

- *Bisection search radically reduces computation time – being smart about generating guesses is important*
- *Should work well on problems with "ordering" property – value of function being solved varies monotonically with input value*
  - *Here ans*ans which grows as ans grows*

Summary

- **Iteration Control**
  - Loop Statements
    - **for**, **while**, **do-while** structures
  - **break** and **continue**
  - Some simple numerical programs

Next week

- **Functions**
  - Definitions
  - Invocation
  - Parameter Lists
  - Return Values
  - Prototypes
- **Variable Scopes**
  - Block Structure
  - Global and Local Variables
  - Static Variables
- **Recursion**