CSE 142
Computer Programming I

Iteration

Overview

Concepts this lecture

- **Iteration - repetitive execution**
- **Loops and nested loops**
- **while statements**
- **for statements**

Chapter 5

Read Sections 5.1-5.6, 5.10

- **5.1 Introduction**
- **5.2-5.3 While statement**
- **5.4 For statement**
- **5.5-5.6 Loop design**
- **5.7 Nested Loops**
- **5.11 Common errors**

An Old Friend: Fahrenheit to Celsius

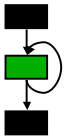
```
#include <stdio.h>
int main(void) {
    double fahrenheit, celsius;
    int nRead;
    printf("Enter a Fahrenheit temperature: ");
    nRead = scanf("%lf",  &fahrenheit);
    if (nRead != 1) {
            printf("Bad input\n");
            return –1;
    }
    celsius =  (fahrenheit - 32.0) * 5.0 / 9.0;
    printf("That equals %f degrees Celsius.",
            celsius);
    return 0;
}
```


What's "Wrong" with Fahrenheit/Celsius Program?

- **User has to rerun the program for every new temperature**
  - **Wouldn't it be nice if the program could process repeated requests?**
- **Program ends immediately if user types a bad input**
  - **Wouldn't it be nice the program politely asked the user again (and again, etc. if necessary)?**

One More Type of Control Flow

Sometimes we want to repeat a block of code. This is called a *loop*.



Loops

A "loop" is a repeated ("iterated") sequence of statements

Like conditionals, loops (iteration) give us a huge increase in the power of our programs

Alert: loops are harder to master than *if* statements

Even experienced programmers often make subtle errors when writing loops

H1-7

Motivating Loops

Problem: add 4 numbers entered at the keyboard.

```
int sum;
int x1, x2, x3, x4;

printf("Enter 4 numbers: ");
scanf("%d%d%d%d", &x1, &x2, &x3, &x4);
sum = x1 + x2 + x3 + x4;
```

This works perfectly!

But... what if we had 14 numbers? or 40? or 4000?

H1-8

Finding Repeated Code

The key to using loops to solve a problem is to discover steps that can be repeated

Our first algorithm for adding four numbers had no repeated statements at all

But it does have some repetition buried in it.

Let's rework the algorithm to make the repetition more explicit

H1-9

Add 4 Numbers, Repetitively

```
int sum,  x;
sum = 0;
printf("Enter 4 numbers: ");

scanf("%d", &x);
sum = sum + x;

scanf("%d", &x);
sum = sum + x;

scanf("%d", &x);
sum = sum + x;
```

H1-10

```
scanf("%d", &x);
sum = sum + x;
```

Loop to Add 4 Numbers

```
int sum,  x;
sum = 0;
printf("Enter 4 numbers:");

scanf("%d", &x);
sum = sum + x;

scanf("%d", &x);
sum = sum + x;

scanf("%d", &x);
sum = sum + x;

scanf("%d", &x);
sum = sum + x;
```

```
int sum,  x;
int count;

sum = 0;
printf("Enter 4 numbers:");

count = 1;
while (count <= 4) {
    scanf("%d", &x);
    sum = sum + x;
    count = count + 1;
}
```

H1-11

while Statement Syntax

Loop condition

```
while ( condition ) {
    statement1;
    statement2;
    …
}
```

Loop body: Any statement, or a compound statement

H1-12

More General Loop to Add Numbers

```
int sum, x, count;
int number_inputs;          /* Number of inputs */

sum = 0;
printf("How many numbers? ");
scanf("%d", &number_inputs);
printf("Enter %d numbers: ", number_inputs);
count = 1;
while ( count <= number_inputs ) {
   scanf("%d", &x);
   sum = sum + x;
   count = count + 1;
}
```

H1-13

Compute 7!

What is 1 * 2 * 3 * 4 * 5 * 6 * 7? ("seven factorial")

```
x = 1 * 2 * 3 * 4 * 5 * 6 * 7;
printf ( "%d", x ) ;
```

Bite size pieces:

```
x = 1;
x = x * 2;
x = x * 3;
x = x * 4;
x = x * 5;
x = x * 6;
x = x * 7;
```

More Regular:

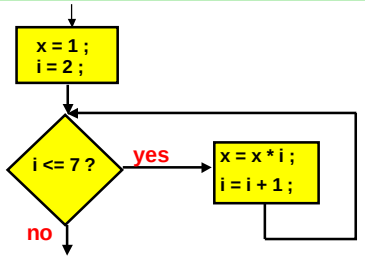
```
x = 1;    i = 2;
x = x * i;  i = i + 1;
x = x * i;  i = i + 1;
x = x * i;  i = i + 1;
x = x * i;  i = i + 1;
x = x * i;  i = i + 1;
x = x * i;  i = i + 1;
```

As a loop:

```
x = 1;
i = 2;
while ( i <= 7 ) {
   x = x * i;
   i = i + 1;
}
```

H1-14

while Loop Control Flow



H1-15

Tracing the Loop

```
/* What is 1 * 2 * 3 * ...*7   */
x = 1 ;                 /* A */
i = 2 ;                 /* B */
while ( i <= 7 ) {      /* C */
   x = x * i ;          /* D */
   i = i + 1 ;          /* E */
}                       /* F */
printf ( "%d", x ) ;    /* G */
```

line	i	x	i≤7?
A	?	1	
B	2	1	
C	2	1	T
D	2	2	
E	3	2	
C	3	2	T
.....			
C	6	120	T
D	6	720	
E	7	720	
C	7	720	T
D	7	5040	
E	8	5040	
C	8	5040	F
G	(Print 5040)		

H1-16

Double Your Money

```
/* Suppose your $1,000 is earning interest
at 5% per year.  How many years until you
double your money? */

my_money = 1000.0;
n = 0;
while ( my_money  <  2000.0 ) {
    my_money  =  my_money *1.05;
    n = n + 1;
}
printf( "My money will double in %d years.", n);
```

H1-17

Average Inputs

```
printf ( "Enter values to average, end with -1.0 \n") ;
sum  =  0.0 ;                          sentinel
count  =  0 ;
scanf ( "%lf", &next ) ;
while ( next  !=  -1.0 )  {
    sum   = sum + next ;
    count = count + 1;
    scanf ( "%lf", &next ) ;
}
if  (count  >  0)
    printf( "The average is %f. \n",
                sum / (double) count );
```

H1-18

Printing a 2-D Figure

How would you print the following diagram?

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

repeat 3 times
print a row of 5 stars

repeat 5 times
print *

It seems as if a loop within a loop is needed

H1-19

Nested Loop

```
#define ROWS    3
#define COLS    5
…
row = 1;
while ( row  <=  ROWS ) {
   /* print a row of 5 *'s */
      …
   row =  row + 1;
}
```

H1-20

Nested Loop

```
row = 1;
while ( row  <=  ROWS ) {
   /* print a row of 5 *'s */
   col = 1;
   while (col <= COLS) {
      printf("*");
      col = col + 1;
   }
   printf( "\n" );
   row =  row + 1;
}
```

outer loop: print 3 rows

inner loop: print one row

H1-21

Trace

row: 1 2 3 4

col: 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6

output:

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

```
row = 1;
while ( row  <=  ROWS ) {
   /* print a row of 5 *'s */
   col = 1;
   while (col <= COLS) {
      printf("*");
      col = col + 1;
   }
   printf( "\n" );
   row =  row + 1;
}
```

H1-22

Print a Multiplication Table

	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9
4	4	8	12

	1	2	3
1	1 * 1	1 * 2	1 * 3
2	2 * 1	2 * 2	2 * 3
3	3 * 1	3 * 2	3 * 3
4	4 * 1	4 * 2	4 * 3

H1-23

	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9
4	4	8	12

Print Row 2

```
col = 1;
while (col <= 3) {
   printf("%4d", 2 * col );
   col = col + 1;
}
printf("\n");
```

row number

H1-24

Nested Loops

Print 4 rows

Print one row

```
row = 1;
while (row <= 4)  {
    col = 1;
    while (col <= 3) {
        printf("%4d",  row  * col );
        col = col + 1;
    }
    printf("\n");
    row = row + 1;
}
```

H1-25

Loop Trace

row	col	
1	1	print 1
	2	print 2
	3	print 3
		print \n
2	1	print 2
	2	print 4
	3	print 6
		print \n

row	col	
3	1	print 3
	2	print 6
	3	print 9
		print \n
4	1	print 4
	2	print 8
	3	print 12
		print \n

H1-26

Notes About Loop Conditions

- They offer all the same possibilities as conditions in *if*-statements
  - Can use &&, ||, !
- Condition is reevaluated each time through the loop
- A common loop condition: checking the number of times through the loop

H1-27

Counting Loops

A common loop condition: checking the number of times through the loop

Requires keeping a "counter"

This pattern occurs so often there is a separate statement type based on it: the *for*-statement

H1-28

A *for* Loop

```
/* What is 1 * 2 * 3 * ... * n ? */
```

```
x = 1 ;
i = 2 ;
while (  i <= n  )  {
    x = x * i ;
     i = i+1;
}
printf ( "%d", x ) ;
```

```
x = 1 ;
for  ( i = 2 ; i <= n ; i = i+1 ) {
    x = x * i ;
}
printf ( "%d", x) ;
```

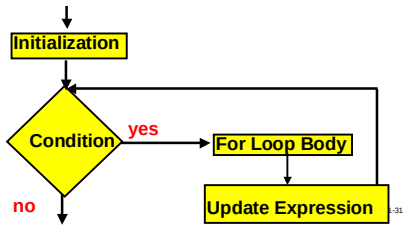
H1-29

for Statement Syntax

```
for ( initialization;
      condition;
      update expression)  {
    statement1;
    statement2;
    ...
}
```

H1-30

for Loop Control Flow



H1-31

for Loops vs *while* Loops

Any for loop can be written as a while loop

These two loops mean exactly the same thing:

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

initialization;
while (condition) {
        statement;
        update;
}
```

H1-32

Counting in *for* Loops

```
/* Print n asterisks */
for ( count = 1 ; count <= n ;  count = count + 1 ) {
    printf ( "*" ) ;
}
```

```
/* Different style of counting */
for (  count = 0 ; count < n ;  count = count + 1 ) {
    printf ( "*" );
}
```

H1-33

"3 Rows of 5" as a Nested *for* Loop

```
#define ROWS    3
#define COLS    5
...
for ( row = 1;  row  <=  ROWS ;  row =  row + 1 ) {
    for ( col = 1 ;  col <= COLS ;  col = col + 1 ) {
        printf( "*");
    }
    printf( "\n" );
}
```

inner loop: print one row

outer loop: print 3 rows

H1-34

Yet Another 2-D Figure

How would you print the following diagram?

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

For every row (row = 1, 2, 3, 4, 5)

    Print row stars

H1-35

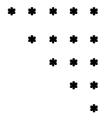
Solution: Another Nested Loop

```
#define ROWS 5
...
int  row, col ;
for ( row = 1 ;  row <= ROWS ;  row = row + 1 ) {
    for ( col = 1 ;  col <= row ;  col = col + 1) {
        printf( "*" ) ;
    }
    printf( "\n" );
}
```

H1-36

Yet One More 2-D Figure

How would you print the following diagram?



For every row (row = 0, 1, 2, 3, 4)

Print row spaces followed by (5 - row) stars

H1-37

Yet Another Nested Loop

```
#define ROWS 5
...
int  row, col ;
for ( row = 1 ;  row <= ROWS;  row = row + 1 ) {
    for ( col = 1 ;  col <= row - 1;  col = col + 1)
        printf( "  " ) ;
    for ( col = row ;  col <= ROWS;  col = col + 1)
        printf( "*" ) ;
    printf( "\n" );
}
```

H1-38

A use for Functions

```
/* Print character ch n times */
void repeat_chars ( int n, char ch) {
    int i ;
    for ( i = 1 ;  i <= n ;  i = i + 1 )
        printf ( "%c", ch) ;
}
...
for ( row = 1 ;  row <= ROWS ;  row = row + 1 ) {
    repeat_chars ( row - 1,  ' ' ) ;
    repeat_chars ( ROWS – row + 1, '*' ) ;
    printf( "\n" );
}
```

H1-39

Some Loop Pitfalls

```
while ( sum < 10 ) ;
   sum = sum + 2;

                for ( i = 1; i <= 10; i = i + 1);
                   sum = sum + i ;

for ( i = 1;  i != 10 ; i = i + 2 )
   sum = sum + i ;
```

H1-40

Double Danger

```
double x ;
for ( x = 0.0 ; x < 10.0 ; x = x + 0.2 )
    printf("%.18f", x) ;
```

Seems harmless...

H1-41

Double Danger

What you expect:	What you might get:
0.000000000000000000	0.000000000000000000
0.200000000000000000	0.200000000000000000
0.400000000000000000	0.400000000000000000
...	...
9.000000000000000000	8.999999999999999997
9.200000000000000000	9.199999999999999996
9.400000000000000000	9.399999999999999996
9.600000000000000000	9.599999999999999996
9.800000000000000000	9.799999999999999996
	9.999999999999999996

H1-42

Use *int*s as Loop Counters

```
int i ;
double x ;
for ( i = 0 ; i < 50 ; i = i + 1 )
{
    x = (double) i / 5.0 ;
    printf("%.18f", x) ;
}
```

H1-43

Counting in Loops

Counting up by one or down by one:

```
for ( i = 1 ;  i <= limit ;  i = i+1 ) { . . . }

times_to_go = limit;
while ( times_to_go > 0 ) {
   • • •
   times_to_go = times_to_go - 1;
}
```

H1-44

Counting Up or Down by 1

This pattern is so common there is special jargon and notation for it

To "increment:" increase (often by 1)
To "decrement:" decrease (often by 1)

C operators:
- Post-increment (x++): add 1
- Post-decrement (x--): subtract 1

H1-45

Handy Shorthand x++ x--

Used by itself,
- x++ means the same as x = x+1
- x-- means the same as x = x-1

Very often used with loop counters:

```
for ( i=1 ;  i <= limit ;  i++ ) { . . . }

times_to_go = limit;
while ( times_to_go > 0 ) {
   . . .
   times_to_go--
```

H1-46

...

Surgeon General's Warning

++ and -- are unary operators.

Pre-increment (++x) and pre-decrement (--x) exist, too.

In this course, use ++ and -- only in isolation.

Don't combine these with other operators in expressions! E.g., don't try

```
x = y++ / (3 * --x--)
```

H1-47

Iteration Summary

General pattern:
- Initialize, test, do stuff, repeat . . .

"while" and "for" are equally general in C

Use "for" when initialize/test/update are closely related and simple, especially when counting

H1-48

Looking Ahead

We'll talk more about how to design loops

We'll discuss complex conditional expressions

- Can be used with loops as well as in conditional statements

We'll see "arrays", a powerful new way of organizing data

- Very often used with loops

H1-49