CSE / ENGR 142 Programming I

Iteration

Chapter 5

Read Sections 5.1-5.6, 5.10

- 5.1 Introduction & While Statement
- 5.2 While example
- 5.3 For Loop
- 5.4 Looping with a fixed bound
- 5.5 Loop design
- 5.6 Nested Loops
- 5.10 Debugging Loops

Motivating Loops

Problem: add 5 numbers entered at the keyboard.
Here's a solution:

```
int sum;
int x1, x2, x3, x4, x5;

printf("Enter 5 numbers: ");
scanf("%d%d%d%d%d", &x1, &x2, &x3, &x4, &x5);
sum = x1 + x2 + x3 + x4 + x5;
```

This works perfectly!
But... what if we had 15 numbers? or 50? or 5000?

Loop to Add 5 Numbers

```
int sum,   x;

sum = 0;
printf("Enter 5 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;
scanf("%d", &x);
sum = sum + x;
```

```
int sum,  x;
int count;

sum = 0;
printf("Enter 5 numbers: ");

count = 1;
while (count <= 5) {
    scanf("%d", &x);
    sum = sum + x;
    count = count + 1;
}
```


More General Solution

```
int sum;
int x;
int 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;
}
```


while loops

loop condition

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

loop body

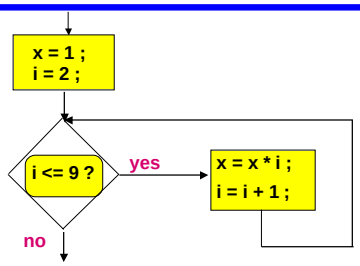
Compute 9!

What is 1 * 2 * 3 * 4 * 5 * 6 * 7 * 8 * 9 ? ("nine factorial")

```
x = 1 * 2 * 3 * 4 * 5 * 6 * 7 * 8 * 9 ;
printf ( "%d", x ) ;
```

Bite size pieces:	More Regular:	Better Still:
x = 1;	x = 1; i = 2;	x = 1;
x = x * 2;	x = x * i; i = i + 1;	i = 2;
x = x * 3;	x = x * i; i = i + 1;	while (i <= 9) {
x = x * 4;	x = x * i; i = i + 1;	x = x * i;
...	...	i = i + 1;
x = x * 9;	x = x * i; i = i + 1;	}

While Loop Control



Tracing the Loop

```
/* What is 1 * 2 * 3 * ... * 9 ?      */

product = 1 ;                    /* A */
i = 2 ;                          /* B */
while ( i <= 9 ) {               /* C */
      product = product * i ;    /* D */
      i = i + 1 ;                /* E */
}                                /* F */
printf ( "%d", product ) ;       /* G */
```

#	i	product	i<=9?
A	?	1	
B	2	1	
C	2	1	T
D	2	2	
E	3	2	
C	3	2	T
D	3	6	
E	4	6	
C	4	6	T
D	4	24	
...	...	...	...
E	10	362880	
C	10	362880	F
G		(print 362880)	

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);
```


Average Inputs

```
printf ( "Enter numbers to average, end with -1.0 \n" ) ;
sum  =  0.0 ;
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 );
```

sentinel

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 *

Nested Loop

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

outer loop: print 3 rows

Nested Loop

```
row = 1;                          (#defines omitted to save space)
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

Trace

row:

col:

output:

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

Print Row 2

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

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

row number

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;
}
```

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
 3    1     print 3
      2     print 6
      3     print 9
       print \n
 4    1     print 4
      2     print 8
      3     print 12
       print \n
```


Loop Trace (Detailed)

```
row  col          statement
 1   ?            1a
 1   ? (TRUE)     1b
 1   1            2a
 1   1 (TRUE)     2b
 1   1  print 1   3
 1   2            2c
 1   2 (TRUE)     2b
 1   2  print 2   3
 1   3            2c
 1   3 (TRUE)     2b
 1   3  print 3   3
 1   4            2c
 1   4 (FALSE)    2b
 1   4  print \n  4
 2   4            1c
 2   4 (TRUE)     1b
 2   1            2a
     . . .
```


for Loops

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

product = 1 ;
i = 2 ;                          /* initialize */
while ( i <= n ) {               /* test */
    product = product * i ;
    i = i+1;                     /* update */
}
printf ( "%d", product ) ;
```

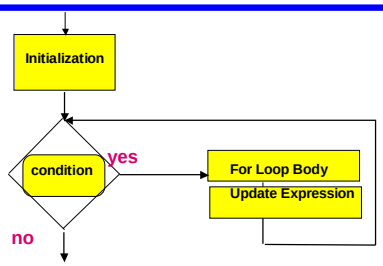
```
product = 1 ;
for ( i = 2 ; i <= n ; i = i+1 ) {
    product = product * i ;
}
printf ( "%d", product ) ;
```


for Loops Syntax

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

"Update" is written at the front of the loop, but executed at the end

for Loop Control Flow



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
}
```

- So *for* provides no new capabilities, but the notation is often convenient.

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 ( "*" );
}
/* could also use count <= n-1 */
```


Another 2-D Figure Puzzle

Print the following diagram with a for loop

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

repeat 3 times
print a row of 5 stars

repeat 5 times
print *

Nested 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" );
}
```

outer loop: print 3 rows

inner loop: print one row

Trace

row:

col:

output:

Yet Another 2-D Figure

How would you print the following diagram?

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

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

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" );
}
```

Trace

row:

col:

output:

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

Yet Another Nested Loop

```
#define ROWS 5
...
int  row, col ;
for ( row = 0 ;  row < ROWS ;  row = row + 1 ) {
    for ( col = 1 ;  col <= row ;  col = col + 1)
        printf( "  " ) ;
    for ( col = 1 ;  col <= ROWS – row ;  col = col + 1)
        printf( "*" ) ;
    printf( "\n" );
}
```


The Appeal of 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", symbol ) ;
}
...
for ( row = 0 ;  row < ROWS ;  row = row + 1 ) {
    repeat_chars ( row, ' ' ) ;
    repeat_chars ( ROWS - row, '*' ) ;
    printf( "\n" );
}
```


Multiplication Table, again

	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

Print Row 2

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

Print one row

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

row number

Nested Loops

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

Print 4 rows

Print one row

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


Nested Loops

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

```
#define ROWS      4
#define COLUMNS   3
. . .
int row, col ;
for (row = 1;  row <= ROWS;  row = row + 1) {      /* 1 a,b,c */
    for (col = 1; col <= COLUMNS; col = col + 1) {  /* 2 a,b,c */
        printf("%4d", row * col ) ;                 /* 3 */
    }
    printf("\n") ;                                  /* 4 */
}
```


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
 3    1     print 3
      2     print 6
      3     print 9
       print \n
 4    1     print 4
      2     print 8
      3     print 12
       print \n
```


Loop Trace (Detailed)

```
row  col          statement
 1   ?            1a
 1   ? (TRUE)     1b
 1   1            2a
 1   1 (TRUE)     2b
 1   1  print 1   3
 1   2            2c
 1   2 (TRUE)     2b
 1   2  print 2   3
 1   3            2c
 1   3 (TRUE)     2b
 1   3  print 3   3
 1   4            2c
 1   4 (FALSE)    2b
 1   4  print \n  4
 2   4            1c
 2   4 (TRUE)     1b
 2   1            2a
      . . .
```


Some Loop Pitfalls

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

```
for ( i = 0; i <= 10; i = i + 1) ;
    sum = sum + i ;
```

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

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


Double Delight

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

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) ;
}
```


Counting in Loops

To "increment:" increase (often by 1)
To "decrement:" decrease (often by 1)
Many loops increment or decrement a loop counter:

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

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


Handy Shorthand

Post-increment (x++), Post-decrement (x--)
Used by itself,
x++ means the same as x = x+1
x-- means the same as x = x-1

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

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


Surgeon General's Warning

- **++ and -- are unary operators.**
- **Pre-increment (++x) and pre-decrement (--x) exist, too.**
- **For CSE142, use only in isolation. Don't combine these with other operators in expressions!**
  E.g., don't try x = y++ / (3 * --x--)

Iteration Summary

- **General pattern:**
  - **initialize**
  - **test**
  - **do stuff**
  - **update**
  - **go back to re-test, re-do stuff, re-update, ...**
- **"while" and "for" are equally general in C**
- **use "for" when initialize/test/update are closely related and simple, especially when counting**

Event-Driven Programming

- Modern programs tend to be "event-driven"
  - Program starts, sets itself up.
  - Waits for some event or command to happen:
    - mouse click, key click, timer, menu selection, etc.
  - Program performs operation ("handles" the command)
  - Program goes back to waiting
- GP142 programs follow this model

Simple Command Interpreter

Read in "commands" and execute them.

Input - single characters

- a -- execute command A by calling *A_handler( )*
- b -- execute command B by calling *B_handler( )*
- q -- quit

Pseudocode for main loop:

- get next command
- if a, execute command A
- if b, execute command B
- if q, signal quit

Command Interpreter Loop Control

repeat until quit signal

use variable "done" to indicate when done

```
set done to false
while not done
    body statements
    if quit command, set done to true
```


Command Interpreter Program

```
#define FALSE 0
#define TRUE  1

int main(void) {
    char command;
    int done;

    done = FALSE;
    while (! done){
                    /* Input command from user */
        printf("Input command: ");
        scanf(" %c", &command);

        switch (command){
        case 'A':
        case 'a':
            A_handler();        /* Execute command A */
            break;
        case 'B':
        case 'b':
            B_handler();        /* Execute command B */
            break;
        case 'Q':
        case 'q':
            done = TRUE;        /* quit */
            break;
        default:
            printf("Unrecognized command\n");
        }
    }
    return 0;
}
```


switch example revisited

```
#define TRUE     1
#define FALSE    0

char marital_status ;
int valid;

valid = FALSE;
while ( ! valid) {
    printf ( "Enter Marital status (M,S): " ) ;
    scanf ( "%c", &marital_status ) ;

    switch ( marital_status  ) {
    case 'm':
    case 'M':
        valid = TRUE;
        printf ( "Married \n" ) ;
        break ;
    case 's':
    case 'S':
        valid = TRUE;
        printf ( "Single \n" ) ;
        break ;
    default:
        printf ( "Sorry, I don't recognize that  code. \n" ) ;
    }
}
```