cs3157 lecture #4 notes.

mon 10 feb 2003

http://www.cs.columbia.edu/~cs3157

- news
  - homework #1 was posted last week, due mon feb 17
  - see adjustments on web page:
    - number of homeworks = 5 (10 points each)
    - number of labs = 10 (3.5 points each)
    - TA assignments
- today's topics
  - logical and bitwise operators, random numbers, character handling
  - file I/O
  - arrays, strings and pointers
  - dynamic memory allocation

logical operators.

- in C are the same as in Java

meaning	C operator
AND	`&&`
OR	`||`
NOT	`!`

- since there are no *boolean* types in C, these are mainly used to connect clauses in `if` and `while` statements
- remember that
  - non-zero $\Rightarrow true$
  - zero $\Rightarrow false$

bitwise operators.

- there are also *bitwise* operators in C, in which each bit is an operand:

meaning	C operator
bitwise AND	`&`
bitwise OR	`|`

- example:

```
int a = 8;  /* this is 1000 in base 2 */
int b = 15; /* this is 1111 in base 2 */
```

```
              1000  (=8)                      1000  (=8)
a & b ⇒     & 1111  (=15)       a | b ⇒     | 1111  (=15)
            ------                          ------
            1000  (=8)                      1111  (=15)
```


logical vs bitwise operators.

- what is the output of the following code fragment?

```
int a = 12, b = 7;
printf( "a && b = %d\n",a && b );
printf( "a || b = %d\n",a || b );
printf( "a & b = %d\n",a & b );
printf( "a | b = %d\n",a | b );
```

random numbers (1).

- with computers, nothing is random (even though it may seem so at times...)
- there are two steps to using random numbers in C:
  1. seeding the random number generator
  2. generating random number(s)
- standard library function:

```
#include <stdlib.h>
```

- seed function:

```
srand( time ( NULL ));
```

- random number function returns a number between `0` and `RAND_MAX` (which is 2^{32})

```
int i = rand();
```


random numbers (2).

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
int main( void ) {
  int r;
  srand( time ( NULL ));
  r = rand() % 100;
  printf( "pick a number between 0 and 100...\n" );
  printf( "was %d your number?", r );
}
```


character handling functions (1).

- character handling library

```
#include <ctype.h>
```

- digit recognition functions (bases 10 and 16)
- alphanumeric character recognition
- case recognition/conversion
- character type recognition
- these are all of the form:

```
int isdigit( int c );
```

where the argument `c` is declared as an `int`, but it is intepreted as a `char`
so if `c = '0'` (i.e., the ASCII value '0', index=48), then the function returns *true* (non-zero int)
but if `c = 0` (i.e., the ASCII value NULL, index=0), then the function returns *false* (0)

character handling functions (2).

digit recognition functions (bases 10 and 16)

- `int isdigit( int c );`
  returns *true* (i.e., non-zero int) if `c` is a decimal digit (i.e., in the range `'0'..'9'`); returns 0 otherwise

- `int isxdigit( int c );`
  returns *true* (i.e., non-zero int) if `c` is a hexadecimal digit (i.e., in the range `'0'..'9','A'..'F'`); returns 0 otherwise

character handling functions (3).

alphanumeric character recognition

- `int isalpha( int c );`
  returns *true* (i.e., non-zero int) if `c` is a letter (i.e., in the range `'A'..'Z','a'..'z'`); returns 0 otherwise

- `int isalnum( int c );`
  returns *true* (i.e., non-zero int) if `c` is an alphanumeric character (i.e., in the range `'A'..'Z','a'..'z','0'..'9'`); returns 0 otherwise

character handling functions (4).

case recognition

- `int islower( int c );`
  returns *true* (i.e., non-zero int) if `c` is a lowercase letter (i.e., in the range `'a'..'z'`); returns 0 otherwise
- `int isupper( int c );`
  returns *true* (i.e., non-zero int) if `c` is an uppercase letter (i.e., in the range `'A'..'Z'`); returns 0 otherwise

case conversion

- `int tolower( int c );`
  returns the value of `c` converted to a lowercase letter (does nothing if `c` is not a letter or if `c` is already lowercase)
- `int toupper( int c );`
  returns the value of `c` converted to an uppercase letter (does nothing if `c` is not a letter or if `c` is already uppercase)

character handling functions (5).

character type recognition

- `int isspace( int c );`
  returns *true* (i.e., non-zero int) if `c` is a space; returns 0 otherwise
- `int iscntrl( int c );`
  returns *true* (i.e., non-zero int) if `c` is a control character; returns 0 otherwise
- `int ispunct( int c );`
  returns *true* (i.e., non-zero int) if `c` is a punctuation mark; returns 0 otherwise
- `int isprint( int c );`
  returns *true* (i.e., non-zero int) if `c` is a printable character; returns 0 otherwise
- `int isgraph( int c );`
  returns *true* (i.e., non-zero int) if `c` is a graphics character; returns 0 otherwise

file I/O (1).

- file handling involves three steps:
  1. opening the file
  2. reading from and/or writing to the file
  3. closing the file
- files in C are *sequential access*
- think of it as a cursor that sits at a position in the file
- with each read and write operation, you move that cursor's position in the file
- the last position in the file is called the "end-of-file" and is typically written as: `<EOF>`
- all the functions described on the next few slides are defined in the `<stdio.h>` header file

file I/O (2).

opening files

- `FILE *fopen( const char *filename, const char *mode );`
- `filename` is a string containing the name of the file you want to open; this file is in the current working directory or else you have to include a full path specification
- `mode` is one of the following:

mode	meaning	cursor position	create file?
`r`	read only	beginning of file	no
`r+`	read/write	beginning of file	no
`w`	write only	beginning of file	yes
`w+`	read/write	beginning of file	yes
`a`	write only	end of file	no
`a+`	read/write	end of file	no

  the last column indicates whether the file is created if it does not exist — this is only done with the `w` modes
- the function returns a value of type `FILE *`, which is a *file pointer* (we'll talk about pointers later today), or NULL if there is an error

file I/O (3).

reading from and writing to files

- these functions are just like `printf` and `scanf`, except that instead of writing to the screen and reading from the keyboard, they write to and read from a file
- for writing to a file:

```
int fprintf( FILE *fp, const char *format /*, args...*/ );
```

  this function returns the number of bytes written
  `fp` is the file pointer of the file you are writing to

- for reading from a file:

```
int fscanf( FILE *fp, const char *format /*, args...*/ );
```

  this function returns the number of bytes read
  `fp` is the file pointer of the file you are reading from

file I/O (4).

closing files

- `int close( FILE *fp );`
  `fp` is the pointer to the file you want to close (the value returned from a previous call to `fopen`)

strings (1).

- storing multiple characters in a single variable
- data type is still `char`
- BUT it has a *length*
- last character the is *terminator*: `'\0'`, aka `NULL`
- string constants are surrounded by *double* quotes: `"`
- example:

```
char s[6] = "ABCDE";
```

strings (2).

- example:

```
char s[6] = "ABCDE";
```

- storage looks like this: | A | B | C | D | E | \0 |
- so with strings, you really only access the values stored at indeces 0 through $length - 2$, since the value stored at $length - 1$ is always `\0`

strings (3).

- printing strings
- format sequence: `%s`
- example:

```
#include <stdio.h>
int main( void ) {
  char str[6] = "ABCDE";
  printf( "str = %s\n", str );
} /* end of main() */
```

- output:

```
ABCDE
```


strings (4).

- string handling library

```
#include <string.h>
```

- functions include:

```
int strlen( char *s );
```

this function returns the number of characters in `s`; note that this is NOT the same thing as the number of characters allocated for the string array

- `int strcmp( const char *s1, const char *s2 );`

"This function returns an integer greater than, equal to, or less than 0, if the string pointed to by s1 is greater than, equal to, or less than the string pointed to by s2 respectively. The sign of a non-zero return value is determined by the sign of the difference between the values of the first pair of bytes that differ in the strings being compared."

- for more information and more string functions, do:

```
unix$ man strcmp
```


arrays (1).

- a string is an *array* of characters
- an array is a "regular grouping or ordering"
- a data structure consisting of related elements of the same data type
- in C, an array has a length associated with it
- arrays need:
  - data type
  - name
  - length
- length can be determined:
  - *statically* — at compile time
    e.g., `char str1[10];`
  - *dynamically* — at run time
    e.g., `char *str2;`

arrays (2).

- defining a variable is called “allocating memory” to store that variable
- defining an array means allocating memory for a group of bytes, i.e., assigning a label to the first byte in the group
- individual array elements are *indexed*
  - starting with 0
  - ending with $length - 1$
- indeces follow array name, enclosed in square brackets (`[ ]`)
  e.g., `arr[25]`

array (3).

character array example

```
#include <stdio.h>
#define MAX 6
int main( void ) {
  char str[MAX] = "ABCDE";
  int i;
  for ( i=0; i<MAX-1; i++ ) {
    printf( "%c", str[i] );
  }
  printf( "\n" );
} /* end of main() */
```


arrays (4).

integer array example

```
#include <stdio.h>
#define MAX 6
int main( void ) {
  int arr[MAX] = { -45, 6, 0, 72, 1543, 62 };
  int i;
  for ( i=0; i<MAX; i++ ) {
    printf( "%d", arr[i] );
  }
  printf( "\n" );
} /* end of main() */
```


pointers (1).

- variables that contain memory addresses as their values
- other data types we’ve learned about in C use *direct* addressing
- pointers facilitate *indirect* addressing
- declaring pointers:
  - pointers indirectly address memory where data of the types we’ve already discussed is stored (e.g., int, char, float, etc.)
  - declaration uses asterisks (*) to indicate a pointer to a memory location storing a particular data type
- example:

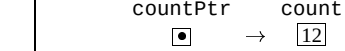
```
int *count;
float *avg;
```

pointers (2).

- ampersand & is used to *dereference* a pointer
- it says: return the address of the variable argument
- example:

```
int count = 12;
int *countPtr = &count;
```

- `&count` returns the *address* of `count` and stores it in the pointer variable `countPtr`
- a picture:



pointers (3).

here's another example:

```
int i = 3, j = -99;
int count = 12;
int *countPtr = &count;
```

and here's what the memory looks like:

variable name	memory location	value
`count`	0xbffff4f0	12
`i`	0xbffff4f4	3
`j`	0xbffff4f8	-99
...		
`countPtr`	0xbffff600	0xbffff4f0
...		

pointers (4).

- an array is some number of contiguous memory locations
- an array definition is really a pointer to the starting memory location of the array
- and pointers are really integers
- so you can perform integer arithmetic on them
- e.g., +1 increments a pointer, -1 decrements
- you can use this to move from one array element to another

pointers (5).

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
int main() {
  int i, *j, arr[5];
  srand( time ( NULL ));
  for ( i=0; i<5; i++ )
    arr[i] = rand() % 100;
  printf( "arr=%p\n",arr );
  for ( i=0; i<5; i++ ) {
    printf( "i=%d arr[i]=%d &arr[i]=%p\n",i,arr[i],&arr[i] );
  }
  j = &arr[0];
  printf( "\nj=%p *j=%d\n",j,*j );
  j++;
  printf( "after adding 1 to j:\n j=%p *j=%d\n",j,*j );
}
```

pointers (6).

and the output is...

```
arr=0xbffff4f0
i=0 arr[i]=29 &arr[i]=0xbffff4f0
i=1 arr[i]=8 &arr[i]=0xbffff4f4
i=2 arr[i]=18 &arr[i]=0xbffff4f8
i=3 arr[i]=95 &arr[i]=0xbffff4fc
i=4 arr[i]=48 &arr[i]=0xbffff500

j=0xbffff4f0 *j=29
after adding 1 to j:
j=0xbffff4f4 *j=8
```


dynamic memory allocation (1).

- *malloc()* allocates a block of memory:

```
void *malloc( size_t size );
```

- lifetime of the block is until memory is freed, with *free()*:

```
void free( void *ptr );
```

- example:

```
int *dynvec, num_elements;
printf( "how many elements do you want to enter? " );
scanf( "%d", &num_elements );
dynvec = (int *)malloc( sizeof(int) * num_elements );
```


dynamic memory allocation (2).

- memory leaks — memory allocated that is never freed:

```
char *combine( char *s, char *t ) {
  u = (char *)malloc( strlen(s) + strlen(t) + 1 );
  if ( s != t ) {
    strcpy( u, s );
    strcat( u, t );
    return u;
  }
  else {
    return 0;
  }
} /* end of combine() */
```

- `u` should be freed if `return 0;` is executed
- but you don't need to free it if you are still using it!

dynamic memory allocation (3).

- note: `malloc()` does not initialize data
- you can allocate and initialize with "calloc":

```
void *calloc( size_t nmemb, size_t size );
```

  – calloc allocates memory for an array of `nmemb` elements of `size` bytes each and returns a pointer to the allocated memory. The memory is set to zero.

- you can also change size of allocated memory blocks with "realloc":

```
void *realloc( void *ptr, size_t size );
```

  – realloc changes the size of the memory block pointed to by `ptr` to `size` bytes. The contents will be unchanged to the minimum of the old and new sizes; newly allocated memory will be uninitialized.

- these are all functions in `stdlib.h`
- for more information: `unix$ man malloc`

more arrays (1).

- "arrays" are defined by specifying an element type and number of elements
  - statically:

```
int vec[100];
char str[30];
float m[10][10];
```

  - dynamically:

```
int *dynvec, num_elements;
printf( "how many elements do you want to enter? " );
scanf( "%d", &num_elements );
dynvec = (int *)malloc( sizeof(int) * num_elements );
```

- for an array containing N elements, indeces are 0..N-1
- stored as a linear arrangement of elements
- often similar to pointers

more arrays (2).

- C does not remember how large arrays are (i.e., no length attribute, unlike Java)
- given:

```
int x[10];
x[10] = 5;  /* error! */
```

- ERROR! because you have only defined x[0]..x[9] and the memory location where x[10] is can become something else...
- `sizeof x` gives the number of bytes in the array
- `sizeof x[0]` gives the number of bytes in one array element
- thus you can compute the length of `x` via:

```
int length_x = sizeof x / sizeof x[0];
```


more arrays (3).

- when an array is passed as a parameter to a function:
  - the size information is not available inside the function
  - array size is typically passed as an additional parameter

```
printArray( x, length_x );
```

  - or globally

```
#define VECSIZE 10
int x[VECSIZE];
```


more arrays (4).

- array elements are accessed using the same syntax as in Java: `array[index]`
- C does not check whether array index values are sensible (i.e., no bounds checking)
- e.g., `x[-1]` or `vec[10000]` will not generate a compiler warning!
- if you're lucky, the program crashes with

```
Segmentation fault (core dumped)
```

more arrays (5).

- C references arrays by the address of their first element
- array is equivalent to `&array[0]`
- you can iterate through arrays using pointers as well as indexes:

```
int *v, *last;
int sum = 0;
last = &x[length_x-1];
for ( v = x; v <= last; v++ )
  sum += *v;
```


more arrays (6).

- example:

```
#include <stdio.h>
#define MAX 12
int main( void ) {
  int x[MAX]; /* declare 12-element array */
  int i, sum;
  for ( i=0; i<MAX; i++ ) { x[i] = i; }
  /* here, what is value of i? of x[i]? */
  sum = 0;
  for ( i=0; i<MAX; i++ ) { sum += x[i]; }
  printf( "sum = %d\n",sum );
} /* end of main() */
```


more arrays (7).

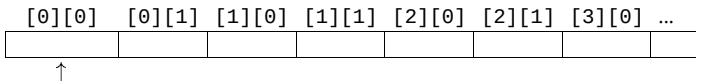
- another example:

```
#include <stdio.h>
#define MAX 10
int main( void ) {
  int x[MAX]; /* declare 10-element array */
  int i, sum, *p;
  p = &x[0];
  for ( i=0; i<MAX; i++ ) { *p = i + 1;  p++; }
  p = &x[0];
  sum = 0;
  for ( i=0; i<MAX; i++ ) {  sum += *p;  p++; }
  printf( "sum = %d\n",sum );
} /* end of main() */
```


2D arrays.

- 2-dimensional arrays

```
int weekends[52][2];
```



- you can use indices or pointer math to locate elements in the array
  - `weekends[0][1]`
  - `weekends+1`
- `weekends[2][1]` is same as `*(weekends+2*2+1)`, but NOT the same as `*weekends+2*2+1` (which is an integer)!