CSE 230 Intermediate Programming in C and C++

Arrays, Pointers and Strings

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Instructor: **Shebuti Rayana**

http://www3.cs.stonybrook.edu/~cse230/

Pointer Arithmetic and Element Size

- If `p` is a pointer to a particular type, then the expression `p + 1` yields the correct machine address for storing or accessing the next variable of that type.
- Valid operations: `p + i, ++p, p += 2` etc.
- If `p` and `q` are both pointing to elements of an array, then `p - q` yields the `int` value representing the number of array elements between them

Example: Pointer Arithmetic

```
int i = 7,*p = &i, *r;
double a[2]={0.1,0.2},*q, *s;
r = p + 1;
q = a; //q points to a[0]
s = q + 1; // s = &a[1]
printf(“%d\n”,(int)r - (int)p);
printf(“%d\n”,(int)s - (int)q);
Printf(“%d\n”,s - q);
```

Example: Pointer Arithmetic

```
printf(“%d\n”,(int)r - (int)p);
```

```
4
```

```
printf(“%d\n”,(int)s - (int)q);
```

```
8
```

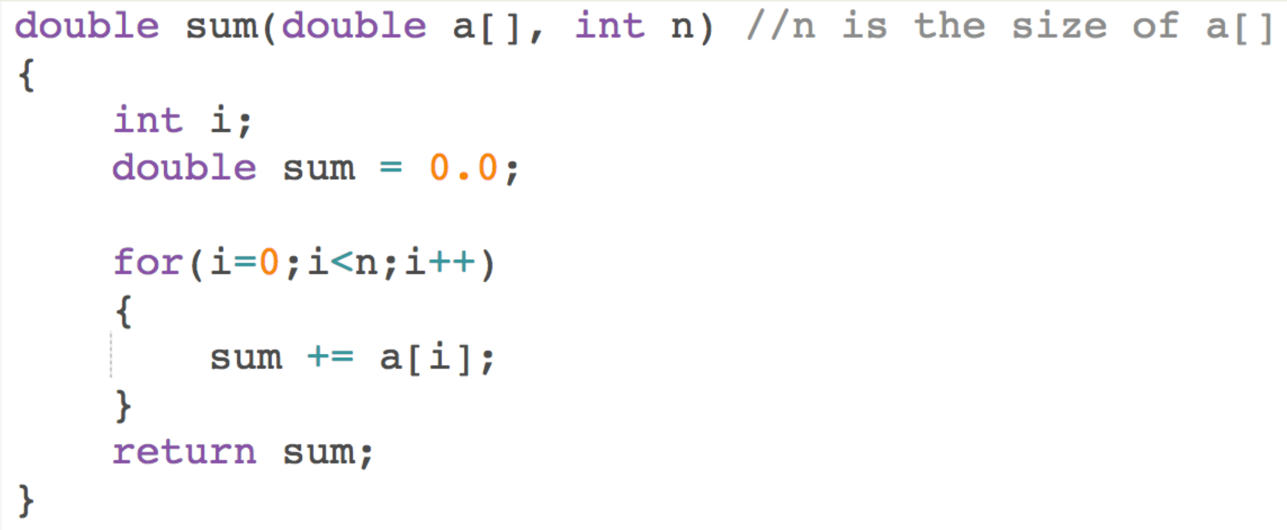
```
Printf(“%d\n”, s - q);
```

```
1
```

- The difference in terms of array elements is 1, but the difference in memory locations is 8 as size of double is 8.

Arrays as Function Arguments

- In function definition, the parameter that is declared as an array is a pointer.
- When an array is passed to a function the base address (&a[0]) is passed, not the elements of the array are copied.
- Example:



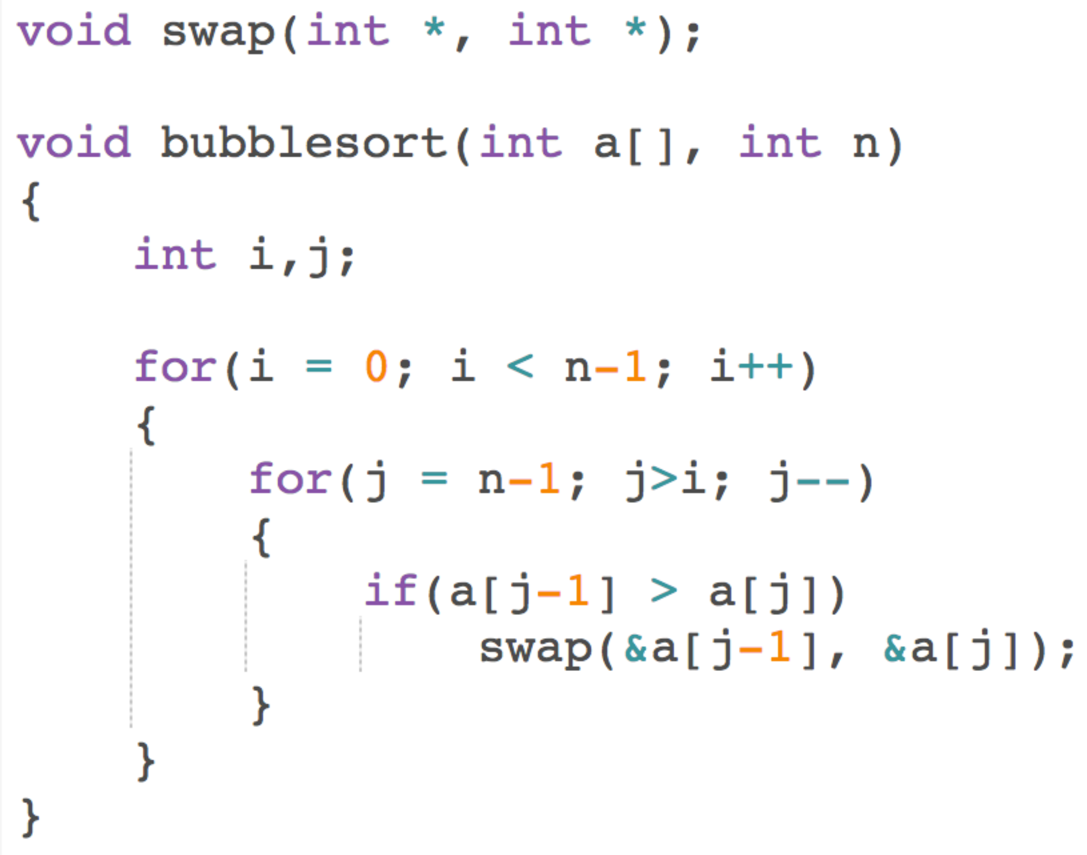
```
double sum(double a[], int n) //n is the size of a[]
{
    int i;
    double sum = 0.0;

    for(i=0;i<n;i++)
    {
        sum += a[i];
    }
    return sum;
}
```

Arrays as Function Argument

- Following two are same:
  `double sum(double a[], int n)`
  `double sum(double *a, int n)`
- Array declaration = pointer declaration in parameter list, but not inside the function body
- From the caller: `sum(a, n);`or `sum(&a[0], n);` both are correct
- `sum(&a[7], k - 7) = a[7], a[8],…, a[k-1]`

An Example: Bubble Sort



```c
void swap(int *, int *);

void bubblesort(int a[], int n)
{
    int i,j;

    for(i = 0; i < n-1; i++)
    {
        for(j = n-1; j>i; j--)
        {
            if(a[j-1] > a[j])
                swap(&a[j-1], &a[j]);
        }
    }
}
```

Bubble sort is expensive takes O(n^2)

Each Pass of Bubble Sort

Unsorted Data	7 3 66 3 -5 22 -77 2
First Pass	-77 7 3 66 3 -5 22 2
Second Pass	-77 -5 7 3 66 3 2 22
Third Pass	-77 -5 2 7 3 66 3 22
Fourth Pass	-77 -5 2 3 7 3 66 22
Fifth Pass	-77 -5 2 3 3 7 22 66
Sixth Pass	-77 -5 2 3 3 7 22 66
Seventh Pass	-77 -5 2 3 3 7 22 66

Dynamic Memory Allocation

- Two standard library functions in `stdlib.h`
  - `calloc()`: Contiguous memory allocation
  - `malloc()`: Memory allocation
- Example usage of `calloc()`:

```
int *a;
int n;
scanf(“%d”,&n);
a = calloc(n,sizeof(int));
```

- The space is initialized with all bits set to 0

Dynamic Memory Allocation (cont.)

- Example `malloc()`:
  ```
  a = malloc(n*sizeof(int));
  ```
- Unlike `calloc()`, `malloc()` does not initialize the memory locations
- In `malloc()` is faster
- Programmer must call `free()` to free the allocated memory with them
- Example: `free(a);`

Strings

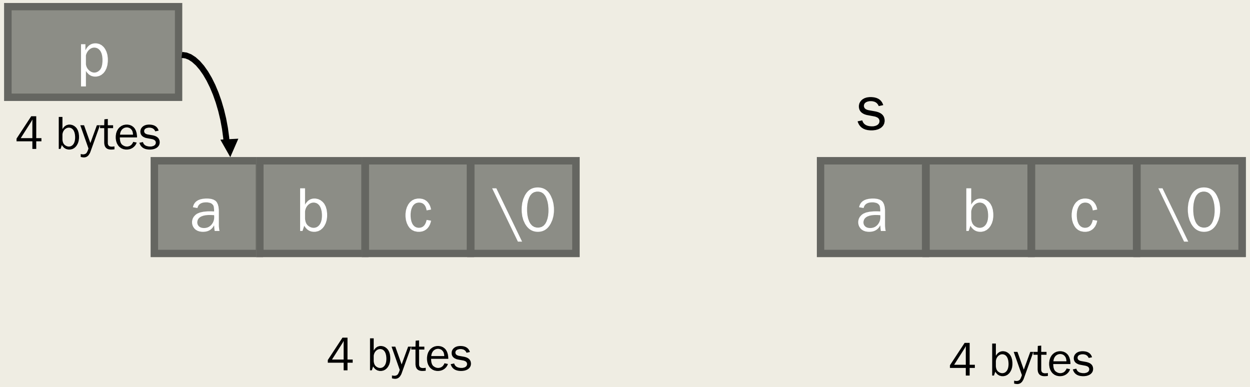
- One-dimensional arrays of type char terminated with end-of-string ‘\0’ or null (byte with all bits off)
- Size must include space for ‘\0’
- String constants are written in double quotes, e.g., “abc” (character array of size 4)
- String constant: “a” (size 2) vs character constant: ‘a’ (size 1)

– Example:

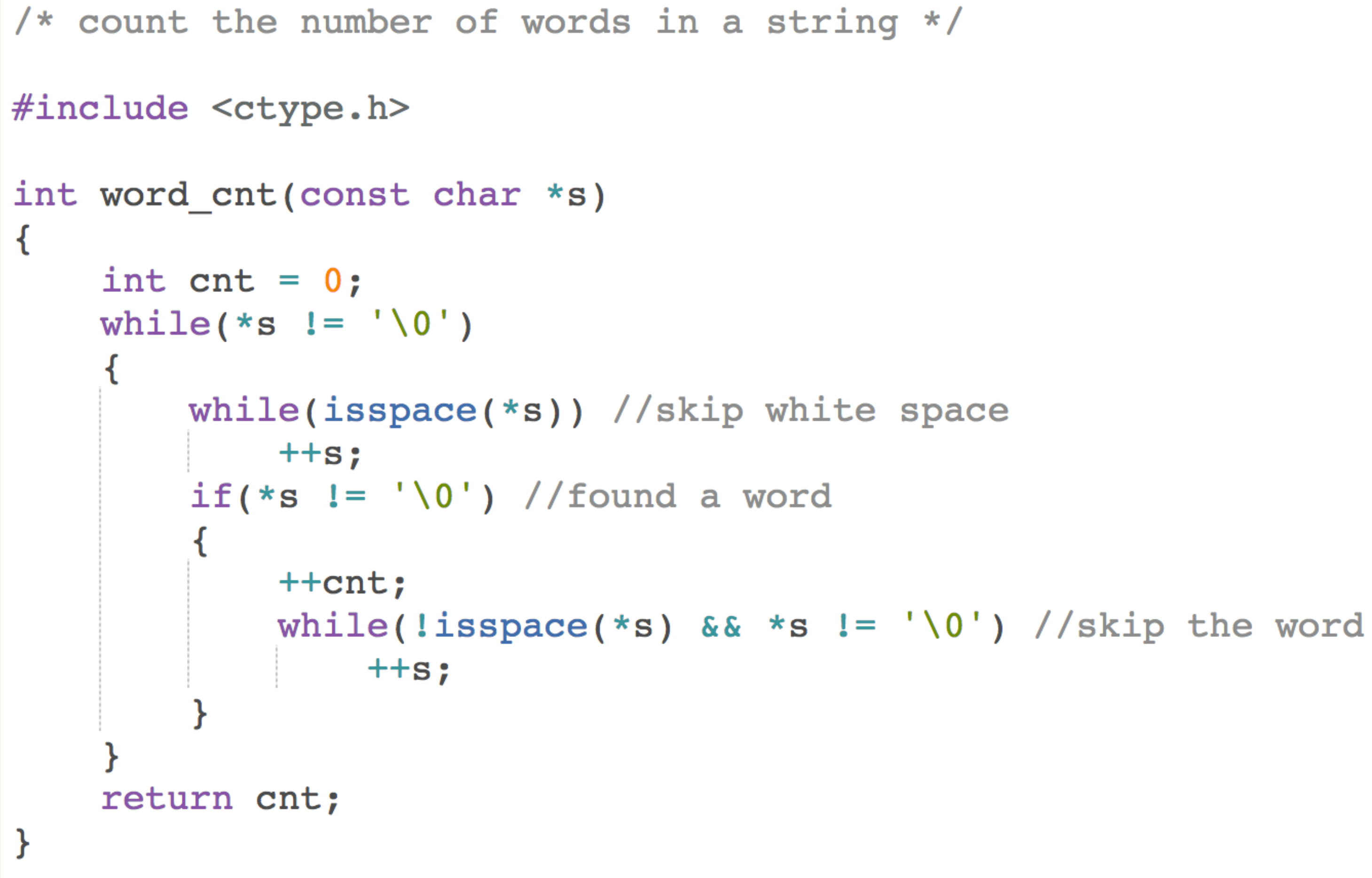
```
char *p = “abc”;
printf(“%s %s\n”, p, p+1);
output: abc bc
```

Strings (cont.)

- A string constant can be treated as a pointer
  - `“abc”[1]` and `*(“abc” + 2)` are legal
- Arrays and pointers differences:
  - `char *p = “abc”; char s[] = “abc”;`



Example: String



```c
/* count the number of words in a string */

#include <ctype.h>

int word_cnt(const char *s)
{
    int cnt = 0;
    while(*s != '\0')
    {
        while(isspace(*s)) //skip white space
            ++s;
        if(*s != '\0') //found a word
        {
            ++cnt;
            while(!isspace(*s) && *s != '\0') //skip the word
                ++s;
        }
    }
    return cnt;
}
```

Library Functions for Strings

- C provide numerous string handling functions in standard library with header `string.h`
- `char *strcat(char *s1, canst char *s2);`
- `int strcmp(const char *s1, const char *s2);`
  - S1 is lexicographically greater, equal or less than s2
- `char *strcpy(char *s1, const char *s2);`
- `size_t strlen(const char *s);`
  - 4 bytes machine size_t is unsigned int

Implementation: strlen()

```
size_t strlen(const char *s)
{
   for (n = 0; *s != '\0'; ++s)
         ++n;
   return n;
}
```

Implementation: strcpy()

```
char *strcpy(char *s1,register const char *s2)
{
    register char *p = s1;
    while(*p++ = *s2++)
        ;
    return s1;
}
```

Implementation: `strcat()`

```
char *strcat(char *s1,register const char *s2)
{
    register char *p = s1;
    while(*p)
        ++p;
    while(*p++ = *s2++)
        ;
    return s1;
}
```

String: Declaration and Initialization

char s1[] = "beautiful big sky country”; char s2[] = "how now brown cow";	
Expression	Value
`strlen(s1)`	25
`strlen(s2+8)`	9
`strcmp(s1, s2)`	Negative integer
Statements	What gets printed
`printf(“%s”,s1+10)`	Big sky country
`strcpy(s1+10, s2+8)`	
`strcat(s1,”s!”)`	
`printf(“%s”,s1)`	Beautiful brown cows!

Two Dimensional Arrays

int a[3][5];
Expression Equivalent to a[i][j]
*(a[i]+j)
(*(a+i))[j]
(((a+i))+j)
*(&a[0][0]+5*i+j)

Three Dimensional Arrays

int a[7][9][2]
Expression Equivalent to a[i][j][k]
*(&a[0][0][0] + 9*2*i + 2*j + k)

Arrays of Pointers

- Arrays of pointers have many use
- An array of `char *` is considered as array of strings
- Example: `char *car_make[9];`

  ```
  char *car_make[9] =
  {"Suzuki","Toyota","Nissan","Tata","BMW"
  ,"Audi","Chevrolet","Honda","Mahindra"};
  ```

- Sort the strings in lexicographic order

Sort in Lexicographic: Example

```
Void sort_word(char *w[], int n) {
    int i, j;
    for(i=0;i<n;++i){
        for(j=i+1;j<n;++j){
            if(strcmp(w[i],w[j])>0)
                swap(&w[i],&w[j]);
        }
    }
}
```

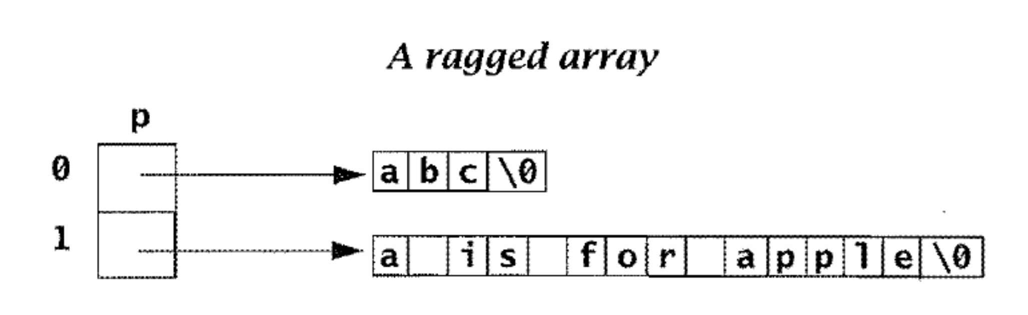
```
void swap(char **p, char **q){
    char *temp;
    temp = *p;
    *p = *q;
    *q = temp;
}
```

Arguments to main()

- Two arguments named `argc` and `argv` can be used with `main()` to communicate with the OS
- Example: `int main(int argc, char *argv[])`
- argc provides a count of the number of command line arguments
- Array `argv` is an array of pointers that are the words that make up the command line. Because the element `argv [0]` contains the name of the command itself, the value of `argc` is at least 1.

Ragged Arrays

- An array of pointers whose elements are used to point to arrays of varying sizes is called a ragged array.



A ragged array

```
char a[2][15] = {"abc:", "a is for
apple"};
```

```
char *p[2] = {"abc:", "a is for
apple"};
```

Functions as Arguments

- In C, pointers to functions can be passed as arguments, used in arrays, returned from function
- **Example:** you want to do an operation with a variety of functions like $\sum_{k=m}^{n} f^2(k)$
- In one instance $f(k) = sin(k)$, in another instance $f(k) = \frac{1}{k}$

Implementation: Function as Argument

```
double sum_square(double f(double x), int m, int n){
     int k;
     double sum = 0.0;
     for (k = m; k <= n; ++k)
          sum += f(k) * f(k);
     return sum;
}
```

```
double f(double x){
    return 1/x;
}

sum_square(f, 1, 100)
```

```
sum_square(sin, 1, 100)
```

Equivalent

```
double sum_square(double (*f)(double x), int m, int n)
```

Type Qualifier `const` and `volatile`

- If a variable is declared with a const type it can not be changed

  ```
  const int k = 3;
  ```

- The `volatile` variables are modified with some unspecified ways by the hardware. Used seldom.