Arrays in C

C Programming and Software Tools

N.C. State Department of Computer Science

Computer Science
NC STATE UNIVERSITY

Contents

- Declaration
- Memory and Bounds
- Operations
- Variable Length Arrays
- Multidimensional Arrays
- Character Strings
- **`sizeof`** Operator

Computer Science
NC STATE UNIVERSITY

Arrays

- Almost any interesting program uses for loops and arrays
- `a[i]` refers to `i`th element of array `a`
  - numbering starts at **0**

☠ *common source of bugs* ☠
referencing first element as a[1]

- Specification of array and index is *commutative*, i.e., `a[i]` references the same value as `i[a]`!

```
days_in_month[0] = 31;
1[days_in_month] = 28;
```


Computer Science NC STATE UNIVERSITY

Declaring Arrays

- The declaration determines the
  1. element datatype
  2. array length (implicit or explicit)
  3. array initialization (none, partial, or full)
- Array length (*bounds*) can be any constant (integer) expression, e.g., **`3`**, **`3*16-20/4`**, etc.

Computer Science NC STATE UNIVERSITY

Declaring 1-D Arrays

- Explicit length, nothing initialized:

```
int   days_in_month[12];
char  first_initial[12];
float inches_rain[12];
```

- Explicit length, fully initialized:

```
int days_in_month[12]
= {31,28,31,30,31,30,31,31,30,31,30,31 };

char first_initial[12]
= {'J','F','M','A','M','J','J','A','S','O','N','D'};

float inches_rain[12]
= {3.5,3.7,3.8,2.6,3.9,3.7,4.0,4.0,3.2,2.9,3.0,3.2};
```

what happens if you try to initialize more than 12 values??

Declaring 1-D… (cont'd)

- Implicit length + full initialization:

```
int days_in_month[]
= {31,28,31,30,31,30,31,31,30,31,30,31 };

char first_initial[]
= {'J','F','M','A','M','J','J','A','S','O','N','D'};

float inches_rain[]
= {3.5,3.7,3.8,2.6,3.9,3.7,4.0,4.0,3.2,2.9,3.0,3.2};
```

The number of values initialized implies the size of the array

Computer Science NC STATE UNIVERSITY

Declaring 1-D… (cont'd)

- Can initialize just selected elements
  - uninitialized values are cleared to 0
- Two styles:

```
int days_in_month[12] = {31,28,31,30,31,30};
char first_initial[12] = {'J','F','M'};
float inches_rain[12] = {3.5,3.7,3.8,2.6,3.9,3.7,4.0,4.0};
```

```
int days_in_month[12] = {[0]=31,[3]=30,[7]=31};
char first_initial[12] = {[2]=`M',[3]='A',[4]='M',[11]='D'};
```


Computer Science NC STATE UNIVERSITY

Declaring 1-D… (cont'd)

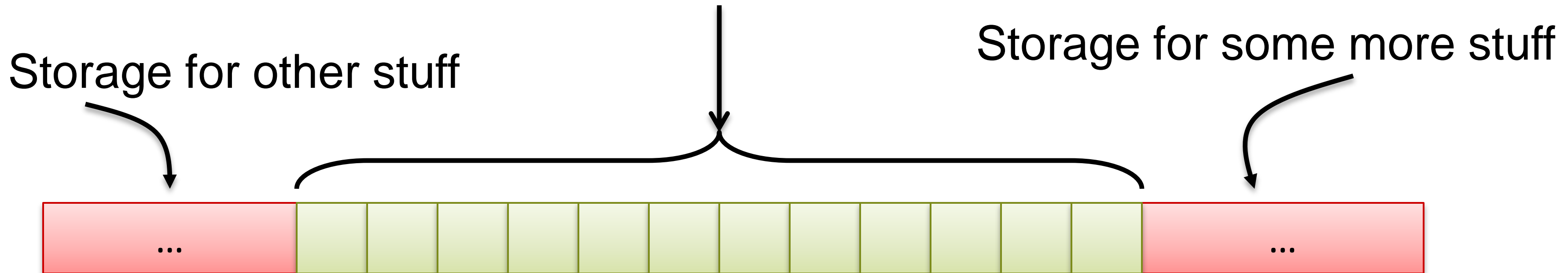
- Implicit array length and partial initialization??

```
char first_initial[] =
     { [0]='J', [2]='M', [8]='S' };
```

How big is this array??

Computer Science
NC STATE UNIVERSITY

Memory Layout and Bounds Checking



(each location shown here is an **int**)

- There is NO bounds checking in C
  - i.e., it's legal (but not advisable) to refer to **days_in_month[216]** or **days_in_month[-35]** !
  - who knows what is stored there?

Computer Science
NC STATE UNIVERSITY

Bounds Checking… (cont'd)

- References outside of declared array bounds
  - may cause program exceptions ("bus error" or "segmentation fault"),
  - may cause other data values to become corrupted, or
  - may just reference wrong values
- Debugging these kinds of errors is one of the hardest errors to diagnose in C

☠ *common source of bugs* ☠
referencing outside the declared bounds of an array

Computer Science
NC STATE UNIVERSITY

Operations on Arrays

- The only built-in operations on arrays are:
  - address of operator (`&`)
  - `sizeof` operator
  - *we'll discuss these shortly…*
- Specifically, there are no operators to…
  - assign a value to an entire array
  - add two arrays
  - multiply two arrays
  - rearrange (permute) contents of an array
  - etc.

Computer Science NC STATE UNIVERSITY

Operations on Arrays?

- Instead of using built-in operators, write loops to process arrays, e.g....

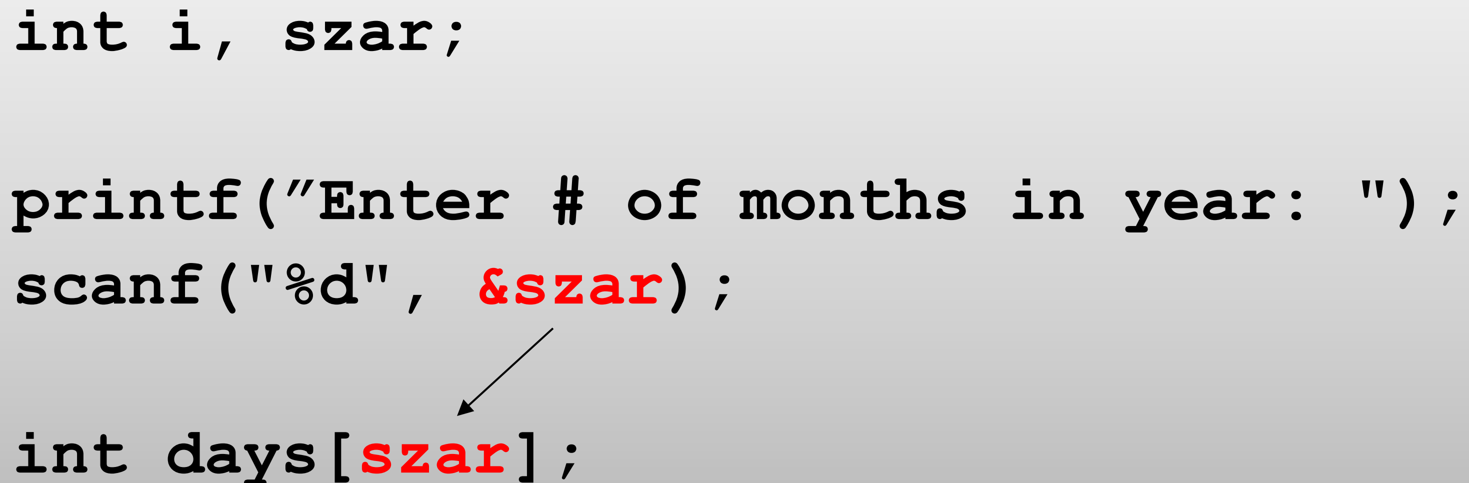
```
int exam1_grade[NUM_STUDENTS],
    hw1[NUM_STUDENTS],
    hw2[NUM_STUDENTS],
    hw_total[NUM_STUDENTS];

for (int j = 0; j < NUM_STUDENTS; j++) {
    exam1_grade[j] = 100;
    hw_total[j] = hw1[j] + hw2[j];
}
```


Computer Science NC STATE UNIVERSITY

Variable Length Arrays

- In C99, array length can be dynamically declared for non-static variables:



```
int i, szar;

printf("Enter # of months in year: ");
scanf("%d", &szar);

int days[szar];
```

what happens if you attempt to allocate an array of size zero, or of negative size??

Computer Science NC STATE UNIVERSITY

Variable… (cont’d)

- However… array lengths cannot change dynamically during program execution

```
int sz1, sz2;
(void) printf(”Enter first # of records: ");
(void) scanf("%d", &sz1);
int recs[sz1];

… do some stuff…

(void) printf(”Enter second # of records: ");
(void) scanf("%d", &sz2);
int recs[sz2];
```

Won’t work! Compile error!

Computer Science
NC STATE UNIVERSITY

Multi-Dimensional (“M-D”) Arrays

- Declaring a multi-dimensional array with explicit length (in all dimensions), no initialization:

```
int xy_array[10][20];
char rgb_pixels[256][256][3];
```

rows

columns

color intensity (r, g, or b)

- Referring to one element of a multi-dimensional array:

```
xyval = xy_array[5][3];
r = rgb_pixels[100][25][0];
```


Computer Science NC STATE UNIVERSITY

M-D Arrays… (cont'd)

- M-D Arrays are really arrays of arrays! i.e.,
  - 2-D arrays (**`xy_array`**) are arrays of 1-D arrays
  - 3-D arrays (**`rgb_pixels`**) are arrays of 2-D arrays, each of which is an array of 1-D arrays
  - etc.
- The following are all valid references

```
rgb_pixels                /* entire array (image)
                                       of pixels */
rgb_pixels[9]               /* 10th row of pixels */
rgb_pixels[9][4]   /* 5th pixel in 10th row */
rgb_pixels[9][4][0]   /* red value of 5th
                              pixel in 10th row  */
```

Initializing M-D Arrays

- With implicit initialization, elements are initialized in "leftmost-to-rightmost" dimension order, e.g.

```
/* 2-D array with 2 rows and 3 columns */
char s2D[2][3] =
    { {'a', 'b', 'c'}, {'d', 'e', 'f'} };

for (int i = 0; i < 2; i++)
    for (int j = 0; j < 3; j++)
        putchar(s2D[i][j]);
```

The above outputs **`abcdef`**

Initializing M-D… (cont'd)

Full initialization, explicit length

```
int i[3][4] =
{ {0, 1, 2, 3},
  {4, 5, 6, 7},
  {8, 9, 10, 11} };
```

Partial initialization, explicit length

```
int i[3][4] =
{ {0, 1},
  {4, 5},
  {8, 9} };
```

Implicit Length for M-D Arrays

- Only the first dimension (row) length can be omitted

OK

```
int i[][3] =
{ {0, 1, 2}, {4, 5, 6} };
```

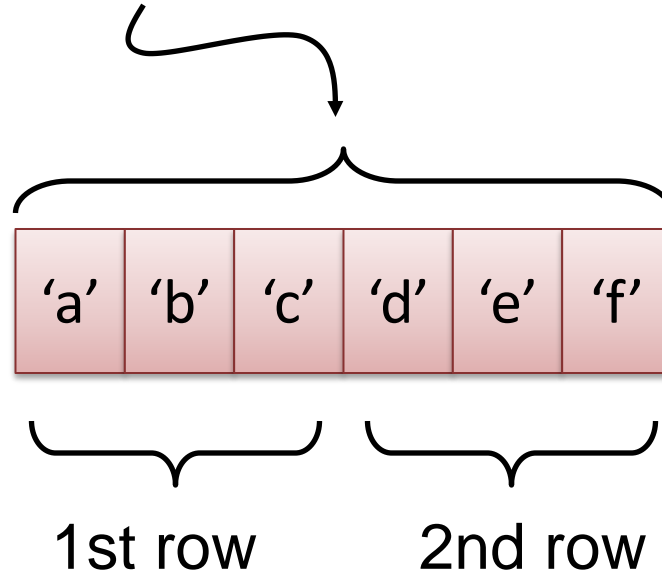
NOT OK

```
int i[2][] =
{ {0, 1, 2}, {4, 5, 6} };
```


Computer Science
NC STATE UNIVERSITY

Memory Layout of M-D Arrays

- Laid out in row-major (leftmost-to-rightmost dimension) ordering



Doesn't matter what the order is, in Java; why should we care in C?

Computer Science
NC STATE UNIVERSITY

Character Strings

- Strings (i.e., sequence of **chars**) are a particularly useful 1-D array
- All the rules of arrays apply, but there are a couple of extra features
- Initialization can be done in the following styles

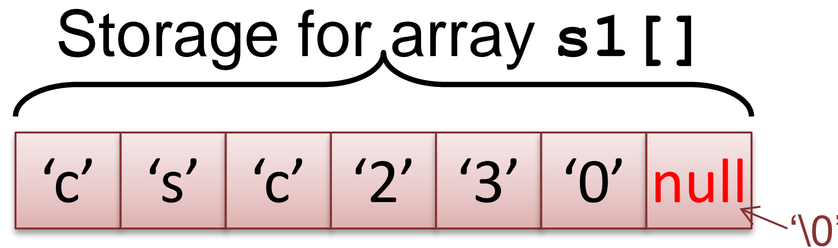
```
char s1[] = "csc230";
char s1[] = { 'c', 's', 'c', '2', '3', '0' };
```

In the first style, the string is implicitly null-terminated by the compiler

- i.e., the array is 7 characters long

☠ *common source of bugs* ☠
failure to null terminate a string

Character Strings (cont’d)



- Null termination is a convenience to avoid the need to specify explicitly the length of a string
  - i.e., functions processing strings can simply look for a null character to recognize the end of the string
  - Ex.: **printf()** prints string of arbitrary length using format specifier **%s** (string must be null terminated)

```
char s1[] = "csc203";
printf ("I'm in %s\n", s1);
```


Computer Science NC STATE UNIVERSITY

Character String Concatenation

- Can initialize a string as a concatenation of multiple quoted initializers:

```
char s1[] = "Now " "is " "the " "time";
printf("%s\n", s1);
```

- Output of execution is:

```
Now is the time
```

```
char s1[] = “This is a really long string that”
            “would be hard to specify in a single”
            “line, so using concatenation is a”
            “convenience.” ;
```


Computer Science
NC STATE UNIVERSITY

The `sizeof` Operator

- Not a function call; a C operator
  - returns number of bytes required by a data type
- Return value is of predefined type **`size_t`**

```
#include <stdlib.h>
size_t tsz1, tsz2, tsz3;
int a;
float b[100];

tsz1 = sizeof (a);
tsz2 = sizeof (b);
tsz3 = sizeof (b[0]);
```

What are these values?

The `sizeof` Operator (cont'd)

Can also be used to determine the number of elements in an array

```
float b[100];
…
int nelems;
nelems = sizeof (b) / sizeof (b[0]);
```

`sizeof()` is evaluated at compile time for statically allocated objects

Computer Science
NC STATE UNIVERSITY

Exercise 08a

Reverse 10

- Write a program that reads 10 integers and prints them in reverse order. Use an array of course.

```
% ./reverse10
2 3 5 7 11 13 17 19 23 29
29 23 19 17 13 11 7 5 3 2
```

CSC230 - C and Software Tools © NC State University Computer Science Faculty

Reminder: Go to course web page for link to exercise form.
Paste code into ideone.com and submit the link.

Computer Science
NC STATE UNIVERSITY

Any Questions?