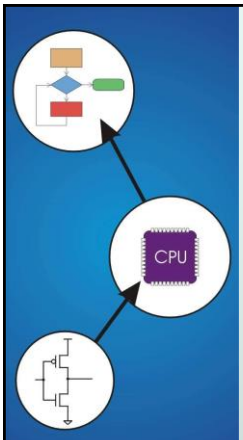


Chapter 16
Pointers and Arrays

Original slides from Gregory Byrd, North Carolina State University

Modified slides by Chris Wilcox, Colorado State University

Pointers and Arrays

- C Pointers and arrays - later we'll see examples of both of these in our LC-3 programs:
- **Pointer**
  - Address of a variable in memory
  - Allows us to indirectly access variables
    - in other words, we can talk about its *address* rather than its *value*
- **Array**
  - A list of values arranged sequentially in memory
  - Example: a list of numbers
  - `array[4]` refers to the 5th element of the array `array`

Address vs. Value

- Sometimes we need the **address** of a memory location, instead of the **value** it contains, e.g.

int array[] = {1234, 2345, 3456, 4567, 5678, 6789 };

address	value
7FFF0100	1234
7FFF0104	2345
7FFF0108	3456
7FFF010C	4567
7FFF0110	5678
7FFF0114	6789

Another Need for Addresses

- Consider the following function that's supposed to swap the values of its arguments.

```
void Swap(int firstVal, int secondVal)
{
    int tempVal = firstVal;
    firstVal = secondVal;
    secondVal = tempVal;
}
```

Pointers in C

- C has explicit syntax for representing addresses – we can talk about and manipulate pointers as variables and in expressions.
  - Declaration

```
int *p;  /* p is a pointer to an int */
float *p;  /* p is a pointer to an float */
```

- A pointer in C points to a particular data type: `int*`, `double*`, `char*`, etc.
  - Operators

`*p` -- returns the value pointed to by p

`&z` -- returns the address of variable z

Example

```
int i;
int *ptr;

i = 4;
ptr = &i;
*ptr = *ptr + 1;
```

store the value 4 into the memory location associated with i

store the address of i into the memory location associated with ptr

read the contents of memory at the address stored in ptr

store the result into memory at the address stored in ptr

Pointers as Arguments

- Passing a pointer into a function allows the function to read/change memory outside its activation record.

```
void NewSwap(int *firstVal, int *secondVal)
{
  int tempVal = *firstVal;
  *firstVal = *secondVal;
  *secondVal = tempVal;
}
```

Arguments are integer pointers. Caller passes addresses of variables that it wants function to change.

Null Pointer

- Sometimes we want a pointer that points to nothing.
- In other words, we're not ready to actually point to something yet.

```
int *p;
p = NULL;  /* p is a null pointer */
```

- `NULL` is a predefined macro that contains a value that a non-null pointer should never hold.
  - NULL =usually equals 0, because address 0 is not a legal address for most programs on most platforms.

Using Arguments for Results

- Pass address of variable where you want result stored
  - useful for multiple results
  - Example:
    - return value via pointer
    - return status code as function result
- This solves the mystery of why '&' with argument to scanf:

```
scanf("%d ", &dataIn);
```

read a decimal integer and store in dataIn

Syntax for Pointer Operators

- **Declaring a pointer**

  `type *var;` or `type* var;`
  - Either of these work -- whitespace doesn't matter
  - Example: `int*` (integer pointer), `char*` (char pointer), etc.
- **Creating a pointer**

  `&var`
  - Must be applied to a memory object, such as a variable (not &3)
- **Dereferencing**
  - Can be applied to any expression. All of these are legal:

```
*var // contents of memory pointed to by var
**var // contents of memory location pointed to
      // by memory location pointed to by var
```


Example using Pointers

- IntDivide performs both integer division and remainder, returning results via pointers.
  - Returns –1 if divide by zero, else 0

```
int IntDivide(int x, int y, int *quoPtr, int *remPtr);
main()
{
    int dividend, divisor;  /* numbers for divide op */
    int quotient, remainder; /* results */
    int error;
    /* ... Input code removed ... */
    error = IntDivide(dividend, divisor,
                      &quotient, &remainder);
    /* ... Remaining code removed ... */
}
```


C Code for IntDivide

```
int IntDivide(int x, int y, int *quoPtr, int *remPtr)
{
     if (y != 0)
     {
        *quoPtr = x / y;  /* quotient in *quoPtr */
        *remPtr = x % y;  /* remainder in *remPtr */
        return 0;
     }
     else
        return -1;
}
```

Arrays

- How do we allocate a group of memory locations?
  - character string
  - table of numbers
- How about this?

```
int num0;
int num1;
int num2;
int num3;
```

- Not too bad, but…
  - what if there are 100 numbers?
  - how do we write a loop to process each number?
- Fortunately, C gives us a better way -- the *array*.

```
int num[4];
```

  - Declares a sequence of four integers, referenced by: `num[0]`, `num[1]`, `num[2]`, `num[3]`.

Array Syntax

- Declaration

```
type variable[num_elements];
```

all array elements are of the same type

number of elements must be known at compile-time

- Array Reference

```
variable[index];
```

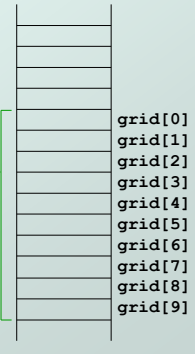
i-th element of array (starting with zero); no limit checking at compile-time or run-time

Array as a Local Variable

- Array elements are allocated as part of the activation record.

```
int grid[10];
```

- First element (`grid[0]`) is at lowest address of allocated space.
- If `grid` is first variable allocated, then R5 will point to `grid[9]`.



Passing Arrays as Arguments

- C passes arrays by reference
  - the address of the array (i.e., of the first element) is written to the function's activation record
  - otherwise, would have to copy each element

```
main() {
  int numbers[MAX_NUMS];
  …
     mean = Average(numbers);
  …
}
int Average(int inputValues[]) {
  …
  for (index = 0; index < MAX_NUMS; index++)
          sum = sum + indexValues[index];
     return (sum / MAX_NUMS);
}
```

This must be a constant, e.g., `#define MAX_NUMS 10`

A String is an Array of Characters

- Allocate space for a string like any other array:

```
char outputString[16];
```

- Space for string must contain room for terminating zero.
- Special syntax for initializing a string:

```
char outputString[16] = "Result = ";
```

- …which is the same as:

```
outputString[0] = 'R';
outputString[1] = 'e';
outputString[2] = 's';
   ...
```


I/O with Strings

- Printf and scanf use "%s" format character for string
  - Printf -- print characters up to terminating zero

```
printf("%s", outputString);
```

  - Scanf -- read characters until whitespace, store result in string, and terminate with zero

```
scanf("%s", inputString);
```


Relationship between Arrays and Pointers

- An array name is essentially a pointer to the first element in the array

```
char word[10];
char *cptr;
cptr = word; /* points to word[0] */
```

- *Difference:*
  - Can change the contents of cptr, as in

```
cptr = cptr + 1;
```

- Why? Because the identifier "word" is not a variable.

Correspondence between Ptr and Array Notation

- Given the declarations on the previous page, each line below gives three equivalent expressions:

`cptr`	`word`	`&word[0]`
`(cptr + n)`	`word + n`	`&word[n]`
`*cptr`	`*word`	`word[0]`
`*(cptr + n)`	`*(word + n)`	`word[n]`

Common Pitfalls with Arrays in C

- **Overrun array limits**
  - There is no checking at run-time or compile-time to see whether reference is within array bounds.

```
int array[10];
int i;
for (i = 0; i <= 10; i++) array[i] = 0;
```

- **Declaration with variable size**
  - Size of array must be known at compile time.

```
void SomeFunction(int num_elements) {
     int temp[num_elements];
     …
}
```


Pointer Arithmetic

- **Address calculations depend on size of elements**
  - To find the fourth element [3] of an integer array, we need to add 12 bytes to the array address.
  - For a double, we would have to add 24 bytes to access the same element.
- C does size calculations under the covers, depending on size of item being pointed to:

```
double x[10];
double *y = x;
*(y + 3) = 13;
```

allocates 80 words, or 10 * sizeof(double)

same as x[3], base address plus 3 * sizeof(double)