Chapter 12

Pointers and Arrays

Introduction

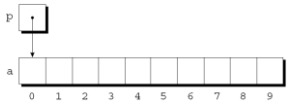
- C allows us to perform arithmetic—addition and subtraction—on pointers to array elements.
- This leads to an alternative way of processing arrays in which pointers take the place of array subscripts.
- The relationship between pointers and arrays in C is a close one.
- Understanding this relationship is critical for mastering C.

Pointer Arithmetic

- Chapter 11 showed that pointers can point to array elements:

```
int a[10], *p;
p = &a[0];
```

- A graphical representation:

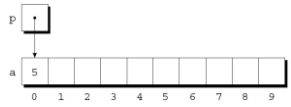


Pointer Arithmetic

- We can now access `a[0]` through `p`; for example, we can store the value 5 in `a[0]` by writing

```
*p = 5;
```

- An updated picture:



Pointer Arithmetic

- If `p` points to an element of an array `a`, the other elements of `a` can be accessed by performing ***pointer arithmetic*** (or ***address arithmetic***) on `p`.
- C supports three (and only three) forms of pointer arithmetic:
  - Adding an integer to a pointer
  - Subtracting an integer from a pointer
  - Subtracting one pointer from another

Adding an Integer to a Pointer

- Adding an integer `j` to a pointer `p` yields a pointer to the element `j` places after the one that `p` points to.
- More precisely, if `p` points to the array element `a[i]`, then `p + j` points to `a[i+j]`.
- Assume that the following declarations are in effect:

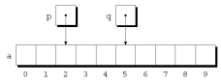
```
int a[10], *p, *q, i;
```

Adding an Integer to a Pointer

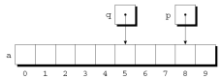
- Example of pointer addition:

```
p = &a[2];
```

```
q = p + 3;
```



```
p += 6;
```

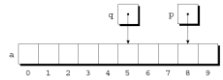


Subtracting an Integer from a Pointer

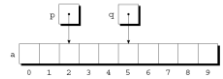
- If `p` points to `a[i]`, then `p - j` points to `a[i-j]`.
- Example:

```
p = &a[8];
```

```
q = p - 3;
```



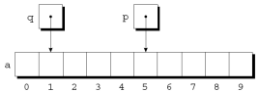
```
p -= 6;
```



Subtracting One Pointer from Another

- When one pointer is subtracted from another, the result is the distance (measured in array elements) between the pointers.
- If `p` points to `a[i]` and `q` points to `a[j]`, then `p - q` is equal to `i - j`.
- Example:

```
p = &a[5];
q = &a[1];
```



```
i = p - q;   /* i is 4 */
i = q - p;   /* i is -4 */
```


Comparing Pointers

- Pointers can be compared using the relational operators (<, <=, >, >=) and the equality operators (== and !=).
  - Using relational operators is meaningful only for pointers to elements of the same array.
- The outcome of the comparison depends on the relative positions of the two elements in the array.
- After the assignments

```
p = &a[5];
q = &a[1];
```

the value of `p <= q` is 0 and the value of `p >= q` is 1.

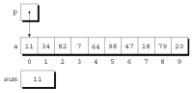
Using Pointers for Array Processing

- Pointer arithmetic allows us to visit the elements of an array by repeatedly incrementing a pointer variable.
- A loop that sums the elements of an array `a`:

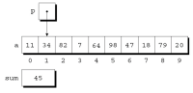
```
#define N 10
…
int a[N], sum, *p;
…
sum = 0;
for (p = &a[0]; p < &a[N]; p++)
  sum += *p;
```


Using Pointers for Array Processing

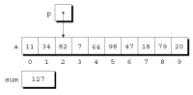
At the end of the first iteration:



At the end of the second iteration:



At the end of the third iteration:



Combining the * and ++ Operators

- C programmers often combine the * (indirection) and ++ operators.
- A statement that modifies an array element and then advances to the next element:

```
a[i++] = j;
```

- The corresponding pointer version:

```
*p++ = j;
```

- Because the postfix version of ++ takes precedence over *, the compiler sees this as

```
*(p++) = j;
```


Combining the * and ++ Operators

- Possible combinations of * and ++:

Expression	*Meaning*
`*p++` or `*(p++)`	Value of expression is `*p` before increment; increment `p` later
`(*p)++`	Value of expression is `*p` before increment; increment `*p` later
`*++p` or `*(++p)`	Increment `p` first; value of expression is `*p` after increment
`++*p` or `++(*p)`	Increment `*p` first; value of expression is `*p` after increment

- The * and -- operators mix in the same way as * and ++.

Combining the * and ++ Operators

- The most common combination of * and ++ is *p++, which is handy in loops.
- Instead of writing

```
for (p = &a[0]; p < &a[N]; p++)
  sum += *p;
```

to sum the elements of the array a, we could write

```
p = &a[0];
while (p < &a[N])
  sum += *p++;
```


Using an Array Name as a Pointer

- Suppose that a is declared as follows:

```
int a[10];
```

- Examples of using a as a pointer:

```
*a = 7;   /* stores 7 in a[0] */
*(a+1) = 12;   /* stores 12 in a[1] */
```

- In general, a + i is the same as &a[i].
  - Both represent a pointer to element i of a.
- Also, *(a+i) is equivalent to a[i].
  - Both represent element i itself.

Using an Array Name as a Pointer

- The fact that an array name can serve as a pointer makes it easier to write loops that step through an array.
- Original loop:

```
for (p = &a[0]; p < &a[N]; p++)
  sum += *p;
```

- Simplified version:

```
for (p = a; p < a + N; p++)
  sum += *p;
```


Using an Array Name as a Pointer

- Although an array name can be used as a pointer, it's not possible to assign it a new value.
- Attempting to make it point elsewhere is an error:

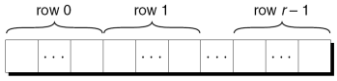
```
while (*a != 0)
  a++;            /*** WRONG ***/
```

- This is no great loss; we can always copy a into a pointer variable, then change the pointer variable:

```
p = a;
while (*p != 0)
  p++;
```

Processing the Elements of a Multidimensional Array

- C stores two-dimensional arrays in row-major order.
- Layout of an array with *r* rows:



- If `p` initially points to the element in row 0, column 0, we can visit every element in the array by incrementing `p` repeatedly.

Processing the Elements of a Multidimensional Array

- Consider the problem of initializing all elements of the following array to zero:

```
int a[NUM_ROWS][NUM_COLS];
```

- The obvious technique would be to use nested `for` loops:

```
int row, col;
…
for (row = 0; row < NUM_ROWS; row++)
  for (col = 0; col < NUM_COLS; col++)
    a[row][col] = 0;
```

- If we view `a` as a one-dimensional array of integers, a single loop is sufficient:

```
int *p;
…
for (p = &a[0][0]; p <= &a[NUM_ROWS-1][NUM_COLS-1]; p++)
  *p = 0;
```


Processing the Rows of a Multidimensional Array

- A pointer variable `p` can also be used for processing the elements in just one *row* of a two-dimensional array.
- To visit the elements of row `i`, we'd initialize `p` to point to element 0 in row `i` in the array `a`:

```
p = &a[i][0];
```

or we could simply write

```
p = a[i];
```


Processing the Rows of a Multidimensional Array

- A loop that clears row `i` of the array `a`:

```
int a[NUM_ROWS][NUM_COLS], *p, i;
…
for (p = a[i]; p < a[i] + NUM_COLS; p++)
  *p = 0;
```

- Since `a[i]` is a pointer to row `i` of the array `a`, we can pass `a[i]` to a function that's expecting a one-dimensional array as its argument.
- In other words, a function that's designed to work with one-dimensional arrays will also work with a row belonging to a two-dimensional array.