Ch 9. Pointers

CS 2308
Spring 2014

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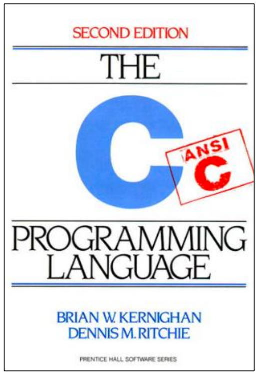
A Quote

A pointer is a variable that contains the address of a variable. Pointers are much used in C, partly because they are sometimes the only way to express a computation, and partly because they usually lead to more compact and efficient code than can be obtained in other ways. Pointers and arrays are closely related; this chapter also explores this relationship and shows how to exploit it.



Pointers have been lumped with the `goto` statement as a marvelous way to create impossible-to-understand programs. This is certainly true when they are used carelessly, and it is easy to create pointers that point somewhere unexpected. With discipline, however, pointers can also be used to achieve clarity and simplicity. This is the aspect that we will try to illustrate.

From: "The C Programming Language (2nd ed.)", Brian W. Kernighan and Dennis M.Ritchie, Englewood Cliffs, NJ: Prentice Hall. 1988. p. 93.

9.1 The Address Operator

- Consider main memory to be a sequence of consecutive cells (1 byte per cell).
- The cells are numbered (like an array). The number of a cell is its **address**.
- When your program is compiled, each variable is allocated a sequence of cells, large enough to hold a value of its type.
- The address operator (&) returns the address of a variable.

```
int x = 99;
cout << x << endl;
cout << &x << endl;
```

Output:

```
99
0xbffffb0c
```

- Addresses in C/C++ are displayed in hexadecimal. [`bffffb0c` = 3,221,224,204]

9.2 Pointer Variables

- A pointer variable (or pointer):
  - contains the *address* of a memory cell
- An asterisk is used to define a pointer variable

```
int *ptr;
```

- "ptr is a pointer to an int" or
- "ptr can hold the address of an int"

```
int * ptr;   //same as above
int* ptr;    //same as above
```

Using Pointer Variables

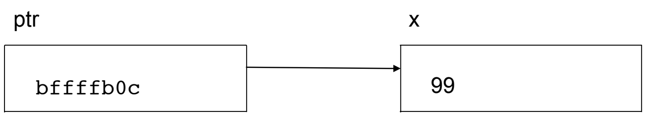
- Assigning an address to a pointer variable:

```
int x = 99;
int *ptr;

ptr = &x;
cout << x << endl;
cout << ptr << endl;
```

Output:

```
99
0xbffffb0c
```



address of x: `0xbffffb0c`

Using Pointer Variables

Another example

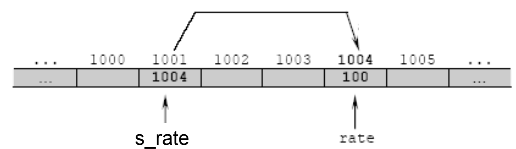
- Assigning an address to a pointer variable:

```
int rate = 100;
int *s_rate;

s_rate = &rate;
cout << rate << endl;
cout << s_rate << endl;
```

Output:

```
100
1004
```

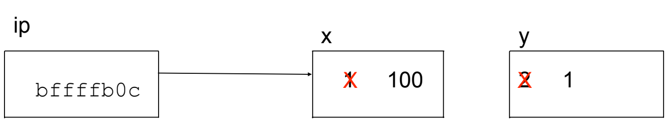


Dereferencing Operator: *

- The unary operator * is the *indirection* or *dereferencing* operator.
- It allows you to access the item that the pointer points to.
- `*ptr` is an alias for the variable that ptr points to.

```
int x = 1;
int y = 2;
int *ip;

ip = &x;     // ip points to x
y = *ip;     // y is assigned what ip points to
*ip = 100;   // (the variable ip points to) gets 100
```



pointer declaration vs. dereferencing

- The asterisk is used in 2 different contexts for pointers, meaning two different things

1. To <u>declare</u> a pointer, in a variable definition:

```
int *ip;       // ip is defined to be a pointer to an int
```

2. To <u>dereference</u> a pointer, in an expression

```
y = *ip;     // y is assigned what ip points to
```

Dereferencing Operator

- Another example

```
int x = 25, y = 50, z = 75;
int *ptr;

ptr = &x;
*ptr = *ptr + 100;

ptr = &y;
*ptr = *ptr + 100;

ptr = &z;
*ptr = *ptr + 100;

cout << x << “ ” << y << “ ” << z << endl;
```


9.3 Pointers and Arrays

- You can use an array variable as if it were a pointer to its first element.

```
int numbers[] = {10, 20, 30, 40, 50};

cout << “first: ” << numbers[0] << endl;
cout << “first: ” << *numbers << endl;

cout << &(numbers[0]) << endl;
cout << numbers << endl;
```

Output:

```
first: 10
first: 10
0xbffffb00
0xbffffb00
```

numbers =

0xbffffb00	10
0xbffffb04	20
0xbffffb08	30
0xbffffb0c	40
0xbffffb10	50

Array is orange

Addresses in white boxes

Pointer Arithmetic

- When you **add a value to a pointer**, you are actually adding that value times the size of the data type being referenced by the pointer.

```
int numbers[] = {10, 20, 30, 40, 50};

// sizeof(int) is 4.
// Let us assume numbers is stored at 0xbffffb00
// Then numbers+1 is really 0xbffffb00 + 1*4, or 0xbffffb04
// And numbers+2 is really  0xbffffb00 + 2*4, or 0xbffffb08
// And numbers+3 is really  0xbffffb00 + 3*4, or 0xbffffb0c
```

Addresses in white boxes

0xbffffb00	10
0xbffffb04	20
0xbffffb08	30
0xbffffb0c	40
0xbffffb10	50

Array is orange

Pointer Arithmetic

- Note unary * has higher precedence than +

```
int numbers[] = {10, 20, 30, 40, 50};

cout << “second: ” << numbers[1] << endl;
cout << “second: ” << *(numbers+1) << endl;

cout << "size: " << sizeof(int) << endl;
cout << numbers << endl;
cout << numbers+1 << endl;
```

Output:

```
second: 20
second: 20
size: 4
0xbffffb00
0xbffffb04
```

- **Note: array[index] is equivalent to *(array + index)**

Pointers and Arrays

- pointer operations can be used with array variables.

```
int list[10];
cin >> *(list+3);
```

- subscript operations can be used with pointers.

```
int list[] = {1,2,3};
int *ptr = list;
cout << ptr[2];
```

- Only difference: you **cannot change** the value of the array variable.

```
double totals[20];
double *dptr;
dptr = totals;    //ok
totals = dptr;    //wrong!!, totals is a const
```


9.4 Pointer Arithmetic

- Operations on pointers to data type d:

```
d *ptr;
```

  - `ptr+n` where n is int: `ptr+n*sizeof(d)`
  - `ptr–n` where n is int: `ptr-n*sizeof(d)`
  - ++ and -- : `ptr=ptr+1` and `ptr=ptr-1` changes ptr to point to next/prev variable of type d
  - += and -=
  - subtraction: `ptr1 – ptr2` result is number of values of type d between the two pointers.

9.5 Initializing Pointers

- Pointers can be initialized when they are defined.

```
int myValue;
int *pint = &myValue;

int ages[20];
int *pint1 = ages;

int *p1 = &myValue, *p2=ages, x=1;
```

note: you are initializing the pointer, NOT what the pointer points to.

- Note: pointers to data type d can be defined along with other variables of type d.

```
double x, y, *d, radius;
```


9.6 Comparing Pointers

- pointers maybe compared using relational operators (based on their address values):
  < <= > >= == !=
- Examples:

```
int arr[25];

cout << (&arr[1] > &arr[0]) << endl;
cout << (arr == &arr[0]) << endl;
cout << (arr <= &arr[20]) << endl;
cout << (arr > arr+5) << endl;
```

- What is the difference?
  - `ptr1 <  ptr2`
  - `*ptr1 < *ptr2`

9.7 Pointers as Function Parameters

- Use pointers to implement pass by reference.

```
//prototype: void changeVal(int *);

void changeVal (int *val) {
   *val = *val * 11;
}

int main() {
   int x;
   cout << "Enter an int " << endl;
   cin >> x;
   changeVal(&x);
   cout << x << endl;
}
```

- How is it different from using reference parameters?

Pointers as array parameter

- Pointer may be used as a parameter for array arg

```
double totalSales(double *arr, int size) {
   double sum = 0.0;
   for (int i=0; i<size; i++) {
      sum += arr[i];              //OR: sum += *arr++;
   }
   return sum;
}

int main() {
   double sales[4];
   // input data into sales here
   cout << “Total sales: “ << totalSales(sales, 4) << endl;
}
```

- What? `sum += *arr++;`

equivalent to:
```
sum = sum + *arr;
arr = arr+1;
```

Note: * and ++ have same precedence, but associate right to left: `*(arr++)`
not: `(*arr)++`

9.8 Dynamic Memory Allocation

- When a function is called, memory for local variables is automatically allocated.
- When a function exits, memory for local variables automatically disappears.
- Must know ahead of time the maximum number of variables you may need.
- Dynamic Memory allocation allows your program to create variables on demand, during run-time.

The new operator

- “new” operator requests dynamically allocated memory for a certain data type:

```
int *iptr;
iptr = new int;
```

- new operator returns <u>address</u> of newly created <u>anonymous</u> variable.
- use dereferencing operator to access it:

```
*iptr = 11;
cin >> *iptr;
int value = *iptr / 3;
```

Dynamically allocated arrays

- dynamically allocate arrays with new:

```
int *iptr;  //for dynamically allocated array
int size;

cout << "Enter number of ints: ";
cin >> size;
iptr = new int[size];

for (int i=1; i<size; i++) {
   iptr[i] = i;
}
```

- Program will throw an exception and terminate if not enough memory available to allocate

delete!

- When you are finished using a variable created with new, use the delete operator to destroy it:

```
int *ptr;
double *array;

ptr = new int;
array = new double[25];
. . .
delete ptr;
delete [] array;  // note [] required for dynamic arrays!
```

- Do not "delete" pointers whose values were NOT dynamically allocated using new!
- Do not forget to delete dynamically allocated variables (Memory Leaks!!).

9.9 Returning Pointers from Functions

- functions may return pointers:

```
int * findZero (int arr[]) {
   int *ptr;
   ptr = arr;
   while (*ptr != 0)
      ptr++;
   return ptr;
}
```

NOTE: the return type of this function is (int *) or pointer to an int.

- The returned pointer must point to
  - dynamically allocated memory OR
  - an item passed in via an argument

NOTE: if the function returns dynamically allocated memory, then it is the responsibility of the calling function to delete it.

Returning Pointers from Functions: duplicateArray

```
int *duplicateArray (int *arr, int size) {

   int *newArray;
   if (size <= 0)           //size must be positive
      return NULL;          //NULL is 0, an invalid address

   newArray = new int [size];  //allocate new array

   for (int index = 0; index < size; index++)
      newArray[index] = arr[index];  //copy to new array

   return newArray;
}
```

```
int a [5] = {11, 22, 33, 44, 55};
int *b = duplicateArray(a, 5);
for (int i=0; i<5; i++)
   if (a[i] == b[i])
      cout << i << " ok" << endl;
delete [] b;  //caller deletes mem
```

Output

```
0 ok
1 ok
2 ok
3 ok
4 ok
```

Problems returning pointers
(watchout)

- Bad:

```
int *getList() {
   int list[80];
   for (int i = 0; i<80; i++)
      list[i] = i;
   return list;
}
```

  - what happens to list on function exit?

- Good:

```
int *getList () {
   int *list;
   list = new int[80];
   for (int i=1; i<80; i++)
      list[i] = i;
   return list;
}
```


Variable Length Arrays

- Using a variable to define the size of a regular array:

```
void f() {
  int size;
  cout << "Enter list length:" << endl;
  cin >> size;
  string list[size]; //size determined at runtime
... }
```

  - what happens to list on function exit?
- Like dynamic arrays, size is determined at runtime
- Unlike dynamic arrays, array is deleted/deallocated at the end of the function.
- This is NOT feature of C++, though g++ supports it.