

Week 4

Pointers & Structs

Gaddis: Chapters 9, 11

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Pointers and Addresses

- The address operator (&) returns the address of a variable.

```
int x;  
cout << &x << endl; // 0xbffffb0c
```

- Pointer: a variable that stores the address of another variable, providing indirect access to it.

- An asterisk is used to define a pointer variable

```
int *ptr;
```

- “ptr is a pointer to an int”. It can contain addresses of int variables.

```
ptr = &x;
```

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Dereferencing and initializing

- The unary operator * is the dereferencing operator.
- *ptr is an alias for the variable that ptr points to.

```
int x = 10;  
int *ptr; //declaration, NOT dereferencing  
ptr = &x; //ptr gets the address of x  
*ptr = 7; //the thing ptr pts to gets 7
```

- Initialization:

```
int x = 10;  
int *ptr = &x; //declaration, NOT dereferencing
```

- ptr is a pointer to an int, and it is initialized to the address of x.

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?

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Pointers and Arrays

- You can treat 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
```

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Pointer Arithmetic

- When you **add a value n to a pointer**, you are actually adding n 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
```

```
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)`

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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];
```

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Comparing Pointers

- pointers (addresses) maybe compared using the relational operators:

`<` `<=` `>` `>=` `==` `!=`

- 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`

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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.

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The new operator

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

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

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

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

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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

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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!!).

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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.

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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
```

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Structures

- A structure stores a collection of objects of **various** types
- Each element in the structure is a member, and is accessed using the dot member operator.

```
struct Student {  
    int idNumber;  
    string name;  
    int age;  
    string major;  
};
```

Defines a new data type

```
Student student1, student2; // Defines new variables  
student1.name = "John Smith";  
Student student3 = {123456, "Ann Page", 22, "Math"};
```

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Structures: operations

- Valid operations over entire structs:

- assignment: student1 = student2;
- function call: myFunc(gradStudent, x);

```
void myFunc(Student, int); //prototype
```

- **Invalid** operations over structs:

- comparison: student1 == student2
- output: cout << student1;
- input: cin >> student2;
- Must do these member by member

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Arrays of Structures

- You can store values of structure types in arrays.

```
Student roster[40]; //holds 40 Student structs
```

- Each student is accessible via the subscript notation.

```
roster[0] = student1; //copy student1 into 1st position
```

- Members of structure accessible via dot notation

```
cout << roster[0].name << endl;
```

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Arrays of Structures: initialization

- To initialize an array of structs:

```
struct Student {
    int idNumber;
    string name;
    int age;
    string major;
};

int main()
{
    Student roster[] = {
        {123456, "Ann Page", 22, "Math"},
        {111222, "Jack Spade", 18, "Physics"}
    };
}
```

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Arrays of Structures

- Arrays of structures processed in loops:

```
Student roster[40];

//input
for (int i=0; i<40; i++) {
    cout << "Enter the name, age, idNumber and "
        << "major of the next student: \n";
    cin >> roster[i].name >> roster[i].age
        >> roster[i].idNumber >> roster[i].major;
}

//output all the id numbers and names
for (int i=0; i<40; i++) {
    cout << roster[i].idNumber << endl;
    cout << roster[i].name << endl;
}
```

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Passing structures to functions

- Structure variables may be passed as arguments to functions:

```
void getStudent(Student &s) { // pass by reference
    cout << "Enter the name, age, idNumber and "
        << "major of the student: \n";
    cin >> s.name >> s.age >> s.idNumber >> s.major;
}

void showStudent(Student x) {
    cout << x.idNumber << endl;
    cout << x.name << endl;
    cout << x.age << endl;
    cout << x.major << endl;
}

// in main:
Student student1;
getStudent(student1);
showStudent(student1);
```

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Pointers to structures

- We can define pointers to structures

```
Student s1 = {12345, "Jane Doe", 18, "Math"};
Student *ptr = &s1;
```

- To access the members via the pointer:

```
cout << *ptr.name << end;    // ERROR: *(ptr.name)
```

- dot operator has higher precedence, so use ():

```
cout << (*ptr).name << end;
```

- or equivalently, use ->:

```
cout << ptr->name << end;
```

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Dynamically Allocating Structures

- Structures can be dynamically allocated with new:

```
Student *sptr;
sptr = new Student;

sptr->name = "Jane Doe";
sptr->idNum = 12345;
...
delete sptr;
```

- Arrays of structures can also be dynamically allocated:

```
Student *sptr;
sptr = new Student[100];
sptr[0].name = "John Deer";
...
delete [] sptr;
```

No arrows (->) necessary.
It's just an array of Student

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