CS 1704

Introduction to Data Structures and Software Engineering

Constructors and Const

- Remember some methods are declared constant?

```
void getObjectID() const;
void CreateAndDestroy::getObjectID() const
{
    return objectID;
}
```

- The "**const**ness" of an object begins as soon as the constructor finishes its job and ends when the destructor is called
- How do we initialize constant member data?

Example

```
class MyClass {
public:
   MyClass(int initial_x);
private:
   const int x; //how do we initialize this?
}
```

Const Problem

- How do you initialize const data when const data has to be initialized when it is declared?
- Through the use of a *member initializer list*

```
MyClass::MyClass(int initial_x) :  x(initial_x)
{
   //whatever else the constructor needs to do
   //we can't do an  "x=initial_x" because x is const!
}
```

Const Problem Solved

- Can use this to initialize all member data
- *Must* use this to initialize const member data

Reference Variable

- The ampersand '`&`' character is used for reference variable declarations:

```
int&   iptr;
float &fptr1, &fptr2;
```

Reference variables are aliases for variables.

  - Reference variables do NOT use the address and dereference operators (`& *`).
  - Compiler dereferences reference variables transparently.

Reference Variable

- Reference variables are constant addresses, assignment can only occur as initialization or as parameter passing, reassignment is NOT allowed.
- Frees programmers from explicitly dereferencing accessing, (in the same way nonpointer variables do).
- 'Cleans up the syntax' for standard **C** arguments and parameters.

Reference Returns

- Return by Value

```
int f(int& a) {
   int b = a;
   // . . .
   return( b );
}//f
```

  - The function does not actually return b, it returns a copy of b.

Reference Returns

- Functions can return references:

```
int& f(int& a) {
   int b = a;
   // . . .
   return( b );
}//f   *** bad ***
```

Good compilers will issue a warning for returning a reference to a local variable.

  - The code above contains a subtle trap. The function returns a reference to a variable b which will no longer exist when the function exits and goes out of scope. Returning a reference to an already referenced variable is acceptable, (although most likely unnecessary and confusing).

Watch Out

- Returning a reference (like a pointer) to a private member
  - Will not work! Why?
- This would break the information hiding, so the compiler will not allow it!
- E.g.:

```
class MC {
 public:
  int& getX() {return &x;}
 private:
  int x;
}
```

Const Pointers as Function Parameters

- Four ways to use const with pointers and functions
  - Non-constant pointer to non-constant data
    - Data can be manipulated and pointer can change
  - Non-constant pointer to constant data
    - Pointer can be made to point to something else, data cannot change
  - Constant pointer to non-constant data
    - Data can be changed, pointer cannot
  - Constant pointer to constant data
    - Nothing can change
  - ☺ Simple, Right?

Examples

```
//pointer to a const char
void printCharacters (const char *sPtr )
{
   for ( ; *sPtr != '\0'; sPtr++ )
        cout << *sPtr;
} //The pointer is changing; data is not
```

More Examples

```
int main()
{  //Can you see the error?
   int x, y;
   int * const ptr = x; //const pointer to an int
   *ptr = 7;
   ptr = &y;
   return 0;
}
```

One more example

```
int main()
{ //Are there errors?
   int x=5,y;
   const int * const ptr = &x; //const pointer to a
                               // const int
   *ptr = 7;
   ptr = &y;
   return 0;
}
```

Pointer Expressions and Pointer Arithmetic

- You can:
  - Increment
  - Decrement
  - Add
  - Subtract
  - Compare
- +1 adds the size of the type
  - E.g. if an int was 4 bites, and an int ptr pointed to 0, ++ptr would point to bite number 4

void *

- void * is a pointer to any type of data
- It should be avoided unless necessary
- A pointer of any type can be cast to a void *
- You cannot dereference a void *
- You must first cast the void * to the type of pointer it is, then dereference

Array Pointer

- Assume we have int b[6] and int * bPtr
- We can do this:
  - bPtr = b; //an array is a pointer!
  - bPtr = &b[0]; //array points to first element
- Also, for example b[3] is:
  - *(bPtr + 3)
  - *(b + 3)
- What does “cout << *b;” print?

Arrays of Pointers

- Consider the following declartion:
  - const char *suit[4] = { “Hearts”, “Diamonds” “Clubs”, “Spades” };
  - How does this compare with a two dimensional array that would normally have to hold these strings?
    - What about in memory?

Dynamic Data ☺

- The programmer can if they wish create an object dynamically.
- Meaning rather than using memory given to the program when it begins and resides in its memory space
- You can get it from the system heap.
- The *new* keyword!

Syntax

- You use the command new
- Time *timePtr;
- timePtr = new Time; //Which constructor?
- timePtr2= new Time(1,2,1980);
- new returns a pointer to the memory allocated for the newly created object of type Time.
- #include <new> to use the new standard

More examples

- You can do this for any built-in or user-defined type
- int *xPtr = new int;
- You can also create an array this way
- int xArrayPtr = new int [10];
- This creates an array of size ten and you access it through xArrayPtr
- cout << xArrayPtr[1];

Freeing memory

- To release the memory pointed to by your pointer you use the command *delete*
- delete xPtr;
- delete [ ] xPtr;
- Forgetting the [ ] on an array only releases the memory for the first location in the array!!!

Pointers to structures:

```
const int f3size = 20;

struct rectype {
  int   field1;
  float field2;
  char  field3[f3size];
};

typedef rectype *recPtr;

rectype rec1 = {1, 3.1415f, "pi"};
recPtr  r1ptr;

r1ptr = &rec1;
```

```
cout << r1ptr->field1
     << r1ptr->field2
     << r1ptr->field3;
```

Logical Expressions for Pointers

- NULL tests:

preferred check

```
if (!person) //true if (person == NULL)
```

- Equivalence Tests:

```
if (person == name)
//true if pointers reference
//the same memory address
//person and name are pointers
```

pointer types must be identical

Deallocation

- Failure to explicitly delete a dynamic variable will result in that memory NOT being returned to the system, even if the pointer to it goes out of scope.
  - This is called a "memory leak" and is evidence of poor program implementation.
  - If large dynamic structures are used (or lots of little ones), a memory leak can result in depletion of available memory.

"Growing" an array

```
int* newArray = new int[newSize];

// copy contents of old array into new one
for (int Idx = 0; Idx < oldCapacity; Idx++)
   newArray[Idx] = Scores[Idx];

// delete old array
delete [] Scores;

// retarget old array pointer to new array
Scores = newArray;

// clean up alias
newArray = NULL;//WHY IS THIS IMPORTANT?
```

nothrow

- An invocation of operator new will fail if the heap does not contain enough free memory to grant the request.
- Traditionally, the value NULL has been returned in that situation. However, the C++ Standard changes the required behavior. By the Standard, when an invocation of new fails, the value returned may or may not be NULL; what is required is that an exception be thrown. We do not cover catching and responding to exceptions in this course.

More nothrow

- the C++ Standard provides a way to force a NULL return **instead** of an exception throw:

```
const int Size = 20;
int* myList = new(nothrow) int[Size];
```

```
// to turn off nothrow warning
#pragama warning (disable:4291)
```

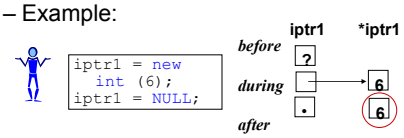
- What should you always do after declaring a new object?
- CHECK TO SEE IF IT WAS NULL!

Pointers Passed

- Passed by value
  - When they do not need to change the pointer value itself
- Passed by reference
  - When they change what the pointer is pointing to
- void add(node *&list, int val) {
  //add is a pointer here
  }

Dynamic Memory Problems

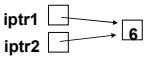
- Garbage
  - Previously allocated memory that is inaccessible thru any program pointers or structures.
  - Example:



Dynamic Memory Problems

- Aliases
  - Two or more pointers referencing the same memory location.
  - Example:

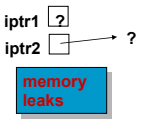
```
iptr1 = new
   int (6);
iptr2 = iptr1;
```



Dynamic Memory Problems

- Dangling Pointers
  - Pointers that reference memory locations previously deallocated.
  - Example:

```
iptr1 = new int (6);
iptr2 = iptr1;
delete iptr1;
```



Dynamic Memory Problems

- Shallow copy
  - The pointer gets the contents of the pointer in the other object…
  - Can you change what one of the pointer points to without changing what the other pointer points to?

Deep Copy

- Solution is to provide what is know as a mechanism for a deep copy
- When you have dynamic data inside of a class, you should always supply three methods

1. Copy Constructor
2. Assignment Operator (overloaded =)
3. Destructor

Copy Constructor

- A copy constructor allows you to successfully create an object that is a copy of another
- e.g. Student NewStudent = OldStudent;
- This would invoke the copy constructor.
- The copy constructor would take care of creating and copying the course information
- Note that NewStudent didn't exist before the statement above

Copy Constructor

```
Student::Student(const Student&
  RHS)
{
  //you perform a memberwise copy
  CoursePtr = new Course[size];
  for ( int i=0; i<Used; i++ )
  {
  CoursePtr[i] = RHS.CoursePtr[i];
  }
}//student has an array of courses
```

Assignment Operator

- An assignment operator allows you to transfer a copy of an already existing object into an already existing object.
- e.g. StudentA = StudentB;
- This is a simple assignment statement.
- The difference between this and a copy constructor is the missing StudentA already exists

Assignment Operator

```
const Student& Student::operator=(const Student& RHS )
{
  if ( this != &RHS )
  {
      delete [] this.CoursePtr;
      //perform memberwise copy
      CoursePtr = new Course [size];
      for ( int i=0; i<Used; i++ )
      {
            CoursePrt[i] = RHS.CoursePtr[i];
      }
  return *this;
}  //Why is a "const Student&" returned?
```

x=y=z;//y=z must return a Student& to be assigned to x

Destructor

```
Student::~Student()
{
  delete [] CoursePtr;
}
```