



Exercise Session W12

Computer Science (CSE & CBB & Statistics) – AS 23

Overview

Today's Agenda

Follow-up

Feedback on **code expert**

Objectives

Memory Management

Exercise "Box"

Common Issues with Pointers

Shared and Unique Pointers

Muddiest Point

Outro



`n.ethz.ch/~agavranovic`

1. Follow-up

Follow-up from previous exercise sessions

- a visualized write-up for `our_list` is now available on Lily's webpage!



`rwko.ch/lily`

2. Feedback on **code** expert

General things regarding **code** expert

General things regarding **code** expert

- All of you have improved a lot - *well done!*

Specific things regarding **code expert**: else

Why do so almost all of you use format the **else** like this?

```
if(condition){
    something();
}

else {
    somehing_else();
}
```


Specific things regarding `code expert`: else

Why do so almost all of you use format the `else` like this?

```
if(condition){
    something();
}

else {
    somehing_else();
}
```

or even *pythonesque*

```
if(condition)
    something();
else
    somehing_else();
```

(It's not wrong. Just *weird*)

Specific things regarding **code expert**: else

Consider formatting them like this

```
if(condition){
    something();
} else {
    something_else();
}
```

Specific things regarding **code expert** : else

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Specific things regarding `code expert`: `else`

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```
void recFoo(std::vector<unsigned int> numbers){
    // BASE CASE
    if(condition){
        return something();
    }

    // LONGER RECURSIVE CASE
    something_else0();
    something_else1();
    something_else2();
    something_else3();
    // ...
}
```

Specific things regarding **code expert**

E8:T2: "Recursive function analysis"

- the grading scheme is pretty strict on this one (one wrong PRE/POST means 1/3 points, only perfect solutions get 3/3)

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- The magic word in these "proofs" is "monotonically decreasing to the base case"
- Returning is not the same as printing **(→//POST)**

Specific things regarding **code expert**

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E8:T3: "Bitstrings up to n"

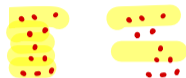
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E8:T4: "Trapezoid Printing"

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Specific things regarding **code expert**



E8:T4: "Trapezoid Printing"

- No recursion \implies No TA-points (again, grading scheme forced me)
- Make sure to check the output of your code yourself and not rely fully on the autograder

Specific things regarding **code expert**

E9:T1: "Reverse Digits"

- You can output expressions directly instead of saving them in a variable first, i.e. instead of

```
int rest = n%10;  
std::cout << rest;  
int new_n = (n-rest)/10;  
reverse(new_n);
```

97 9.7 → 7

- you can do the following:

```
std::cout << n%10;  
reverse(n/10);
```

Questions?

3. Objectives

Objectives

- be able to trace code that uses `new`, `delete`, copy constructors, and destructors.
- understand the common problems related to incorrect use of dynamic memory: dangling pointers, double-free, use-after-free
- be able to define and use shared and unique pointers

4. Memory Management

new and delete

Never forget...

For each **new** a **delete**

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Constructor, Copy-Constructor, Destructor

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- Are just functions which are called at certain events

Never forget...

For each **new** a **delete**

Constructor, Copy-Constructor, Destructor

- Are just functions which are called at certain events
- Must be **public**

Constructor

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- There can be multiple constructors, e.g. for different types. The computer then infers the correct type. For example:

- `personClass Person001(142.0f);`

float

- `personClass Person161(45);`

int

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 - `personClass Person161(45);`
- More on this: [▶ cppreference link](#)

Constructor - Example in a class

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```
class meineKlasse {  
    int a, b;  
    public:  
        const int& r; // for reading only!  
  
    // CONSTRUCTOR  
    meineKlasse(int i)  
        : a(i)          // initializes r to refer to a  
        , b(i+5)        // initializes a to the value of i  
        , r(a)          // initializes b to the value of i+5  
        // ~ 4here we are using a "member initializer list"  
        // and if you want your constructor to do  
        // anything additionally, put it inside  
        { /*here (like in a regular function!)*/ }  
};
```

Member Initializer List

```
meineKlasse::meineKlasse()  
    : memberVariableEins(0)           // init memberVariableEins  
    { memberVariableZwei = 0; }      // init memberVariableZwei
```

What is the difference between these two initializations of the member variables?

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const members

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Performance

- The main reason for us is performance. The code with MILs is faster, as it avoids unnecessary copies. We do not see these copies in the code but they worsen the runtime/performance [▶ good video on this](#)

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- is called when an object of a class/struct is *deconstructed*. This can happen at the end of a scope or when `delete` is used
- is used to keep memory "clean" when an object is no longer in use

Destructor - Example in a class

Destructor - Example in a class

```
class meineKlasse {
    int* value;

public:

    // other -ctors and stuff go here

    ~meineKlasse(){
        delete value; // That's how we clean up the value which
                       // lies at the slot that the int-pointer is
                       // pointing to, instead of just deleting
                       // the int-pointer (avoiding "memory leaks")
    }
};
```

Copy-constructor

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- is called when an object is *initialized* with another object of the same class/struct

Copy-constructor

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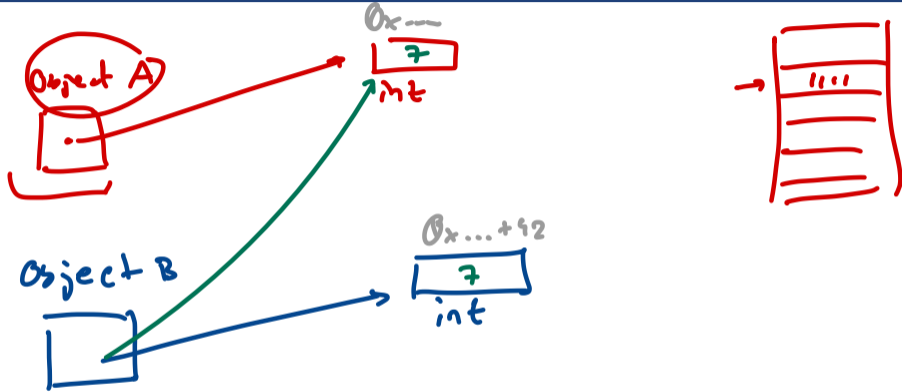
- is called when an object is *initialized* with another object of the same class/struct
- there is a default copy constructor, *if* we don't declare one explicitly. This simply makes a member-wise copy of the class/struct
- lets us precisely determine how we want to copy something instead of simply doing a *shallow copy*

Copy-constructor

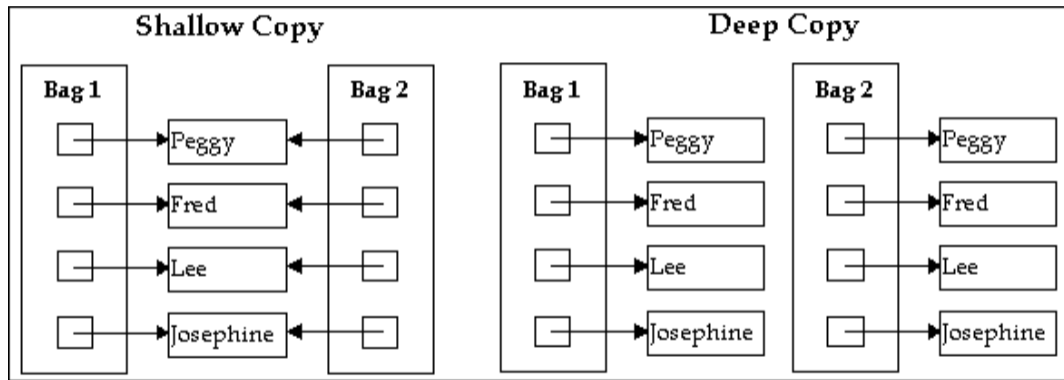
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- there is a default copy constructor, *if* we don't declare one explicitly. This simply makes a member-wise copy of the class/struct
- lets us precisely determine how we want to copy something instead of simply doing a *shallow copy*
- not to be confused with the **operator=**, which does something very similar

Shallow Copy vs. Deep Copy



Shallow Copy vs. Deep Copy



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- *must* have a return type, usually

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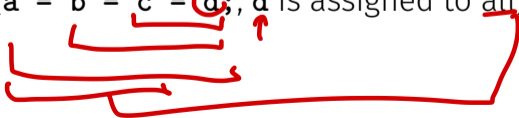
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- is called "assignment operator", just as with primitive types
- Rule of thumb: do destructor stuff first, then copy constructor stuff
- *must* have a return type, usually **class&** so that you can make *chained assignments* (`a = b = c = d;`, `d` is assigned to all)



operator= vs. Copy-Constructor

```
// our class/struct is named "Box"

Box first;           // init by default constructor
Box second(first);  // init by copy-constructor
Box third = first;  // also init by copy-constructor
second = third;     // assignment by (copy-)assignment operator
```

operator= vs. Copy-Constructor

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second = third;     // assignment by (copy-)assignment operator
```

The last two cases look similar, but remember:
the (copy-)assignment-operator= only comes into action *after* an object has already been initialized

Questions?

5. Exercise "Box"

Exercise "Box (copy)"

Here we'll take a *very* close look at the implementation

- Go to **code expert** and open the code example "Box (copy)"

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- Go to **code expert** and open the code example "Box (copy)"
- Don't worry about `main.cpp` yet, we'll get to that
- Don't worry about `std::cerr` either, it's just fancy `std::cout`

- don't use `other.value()`
- no need to check for `nullptr` (in this exercise)

Exercise "Box (copy)"

Here we'll take a *very* close look at the implementation

- Go to **code expert** and open the code example "Box (copy)"
- Don't worry about `main.cpp` yet, we'll get to that
- Don't worry about `std::cerr` either, it's just fancy `std::cout`
- Let's Code Together!

Members of "Box"

```
Box::Box(const Box& other) {  
    ptr = new int(*other.ptr);  
}  
  
Box& Box::operator= (const Box& other) {  
    *ptr = *other.ptr;  
    return *this;  
}
```

Members of "Box"

```
Box::~~Box() {  
    delete ptr;  
    ptr = nullptr;  
}  
  
Box::Box(int* v) {  
    ptr = v;  
}  
  
int& Box::value() {  
    return *ptr;  
}
```

Tracing test_destructor1()

```
void test_destructor1() {
    std::cerr << "[enter] test_destructor1" << std::endl;

    int a;

    {
        Box box(new int(1));
        a = 5;
    }

    std::cout << "a = " << a << std::endl;
    std::cerr << "[exit] test_destructor1" << std::endl;
}
```

Tracing test_destructor2()

```
void test_destructor2() {  
    std::cerr << "[enter] test_destructor2" << std::endl;  
  
    {  
        Box* box_ptr = new Box(new int(2));  
        delete box_ptr;  
    }  
  
    std::cerr << "[exit] test_destructor2" << std::endl;  
}
```

Tracing test_copy_constructor()

```
void test_copy_constructor() {
    std::cerr << "[enter] test_copy_constructor" << std::endl;

    {
        Box demo(new int(0));
        Box demo_copy = demo;

        demo.value() = 4;

        demo_copy.value() = 5;
    }

    std::cerr << "[exit] test_copy_constructor" << std::endl;
}
```

Tracing test_copy_constructor()

Tracing test_assignment()

```
void test_assignment() {
    std::cerr << "[enter] test_assignment" << std::endl;

    {
        Box demo(new int(0));
        demo.value() = 3;
        Box demo_copy(new int(0));
        demo_copy = demo;
        demo.value() = 4;
        demo_copy.value() = 5;
    }

    std::cerr << "[exit] test_assignment" << std::endl;
}
```


Tracing test_assignment()

Questions?

6. Common Issues with Pointers

Dangling Pointers

What?



¹Often referred to as a *Zombie*

Dangling Pointers

What?

A *dangling pointer* arises when a pointer is pointing to a memory location that has been freed or deallocated. Essentially, the pointer is pointing to a place that is no longer valid.¹

How?

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How?

This often occurs when an object is deleted or goes out of scope, but the pointer pointing to it is not set to `nullptr`. As a result, the pointer still refers to the old memory location, despite not knowing what is there now.

So?

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So?

Accessing or manipulating a *dangling pointer* can lead to unpredictable behavior, crashes, or data corruption, as the memory might be reallocated and used for something else.

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Double-Free

What?

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Double-free occurs when `delete` is called twice on the same memory allocation.

How?

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This often occurs in complex programs where memory management is handled in multiple places, leading to confusion about who owns the memory.

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This often occurs in complex programs where memory management is handled in multiple places, leading to confusion about who owns the memory.

So?

Freeing memory twice can corrupt the memory allocation metadata, potentially leading to memory leaks, program crashes, or other erratic behavior.

Use-After-Free

What?

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Use-after-free is a situation where a program continues to use a pointer after it has freed the memory it points to.

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This can happen if the program does not set the pointer to `nullptr` after freeing it, or if there are copies of the pointer that were not updated.

So?

Use-After-Free

What?

Use-after-free is a situation where a program continues to use a pointer after it has freed the memory it points to.

How?

This can happen if the program does not set the pointer to `nullptr` after freeing it, or if there are copies of the pointer that were not updated.

So?

Since the freed memory might be reallocated for other purposes, using it can lead to data corruption, unpredictable program behavior, or security vulnerabilities.

*nullptr

*nullptr



► xkcd

Questions?

Doomed to cause errors?

Doomed to cause errors?

How to prevent all this?

Doomed to cause errors?

How to prevent all this?

Smart Pointers!

7. Shared and Unique Pointers

Smart Pointers

Smart Pointers

- Smart pointers are convenient wrappers around regular pointers that help prevent memory leaks by automatically managing memory
- The smart pointers **shared_ptr** and **unique_ptr** are part of the standard `<memory>` library.

Comparison `unique_ptr` VS `shared_ptr`

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A `unique_ptr` is used for exclusive ownership. Memory associated with a `unique_ptr` is automatically deallocated when they go out of scope.

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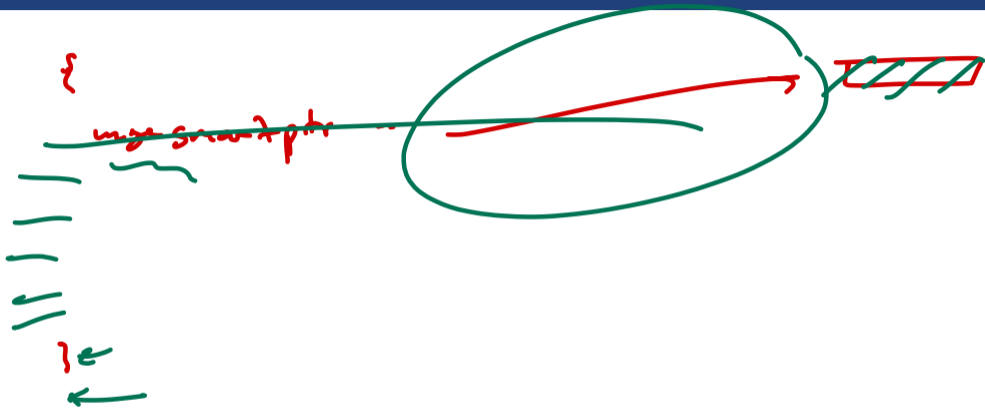
`unique_ptr`

A `unique_ptr` is used for exclusive ownership. Memory associated with a `unique_ptr` is automatically deallocated when they go out of scope.

`shared_ptr`

A `shared_ptr` allows multiple pointers to share ownership of the same resource. It counts how many pointers point to the same resource. Once the count reaches 0, the object is deleted.

Smart Pointers in a nutshell



Smart Pointers in a nutshell



?

+ counter

Questions?

8. Muddiest Point

So, what are you stuck on?

Q&A Session

9. Outro

General Questions?

Hey, let's *get*
together and party!

On Thursday, 7th of
December from 19:00
to 23:00 at CAB D 21

yours truly,
rwko

PS: We'll bring the glühwein and beer!
To Bring your own mug ☺

$\left[\begin{smallmatrix} v \\ mp \end{smallmatrix} \right]$ $[rw::ko]$ voeth

Till next time!

Cheers!