C++ Course 5: Smart Pointers. Miscellanea 1.

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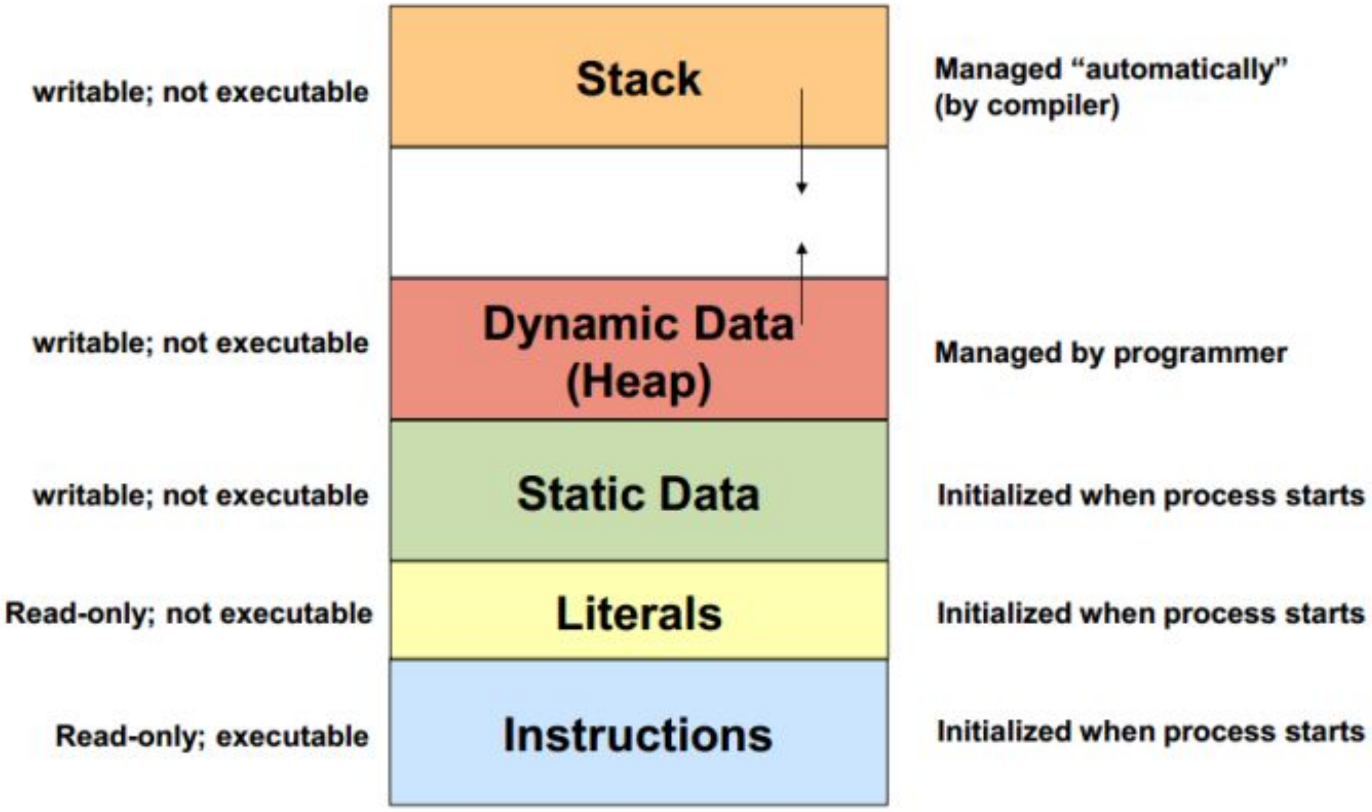
C++ memory model




```
// Local variables
int a;
```

```
int *a = new int;
delete a;
```

```
// Global and "static"
static int a;
```

```
"My string"
```

Object Life Cycle

Every C++ object is born and dies

Scope	Example	Birth	Death
Local variable	**string s = "Jezebel";**	Definition	The closing }
Temporary object	**string("Jack");**	Code line start	Code line end
Global/static variable	**static string("Jill");**	Program start	Program end
Heap object	**new string("Maria");**	**new**	**delete !!!**
Class field	**string s = "Lilith";**	Class Ctor	Class Dtor
Smart pointers	?	?	?

Working with heap memory: new and delete

Old-style C++ (before C++ 11):

```
void fun(){
	string * pS = new string("Some text");
	..
	delete pS;   // Don't forget delete !!! Otherwise a memory leak !
}

class A{
public:
	A(const char * s) : pS(new std::string(s)) {}   // Ctor
	...
	~A(){ delete pS;}   // Dtor
private:
	string * pS;
};
```

Trouble with heap objects 1

```
string * pS = new string("Some text");
```

If we forget **delete:** Memory Leak!

If we put delete twice : double **delete.** Program crashes!

```
delete pS;
delete pS;
```

Things that make it **worse** : multiple returns, exceptions.

```
void fun(){
	string * pS = new string("Some text");
	..
	if (...) return;  // Forgot delete here ! Memory leak !!!
	...
	if (..) throw runtime_error("HAHA !");   // Forgot delete here ! Memory leak !!!
	delete pS;
}
```

Trouble with heap objects 2

There is no way to tell if a pointer points to a valid heap object:

```
string s1("Nel Zelpher");
string *pS1 = &s1;
delete s1; // Wrong ! Not a heap object!
string *pS2 = new string("Sophia Esteed");   // Created a heap object
delete pS2; // Deleted it. OK !
delete pS2; // Error ! Double delete !
int *pI = new int;  // int heap object
string *pS3 = (string *) pI;  // pS3 points to an int heap object (Wrong type !)
delete pS3; // Error ! Wrong type !
```

My program crashes, why ??????

No way to check for these situations !!!

Solution: unique_ptr

unique_ptr takes a heap object under *exclusive ownership*

unique_ptr<string> u = make_unique<string>("Abracadabra"); // C++ 14

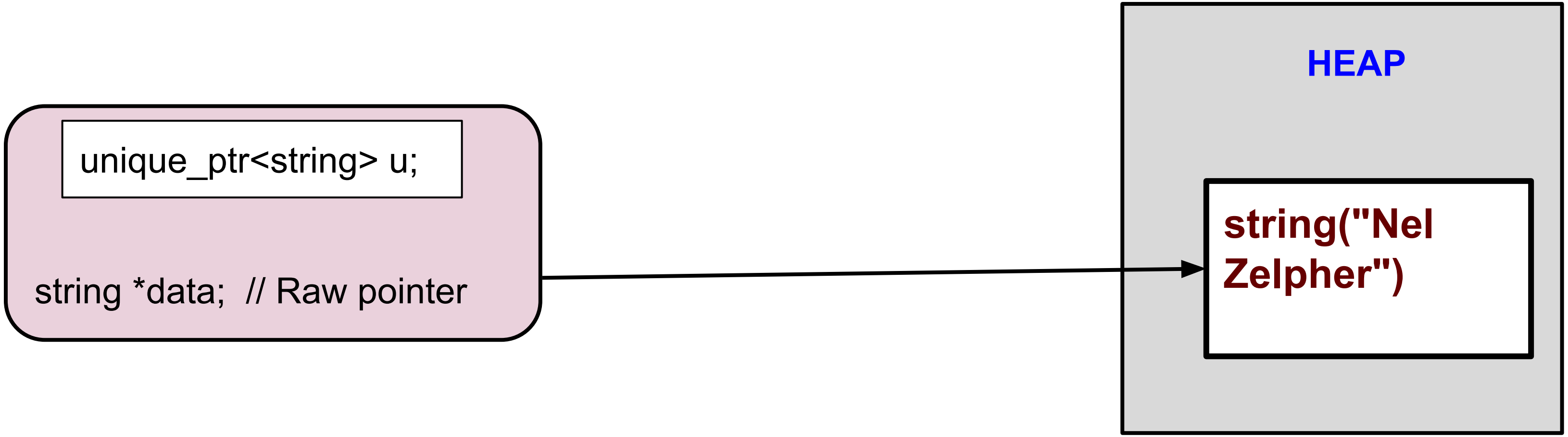
or

unique_ptr<string> u(new string("Abracadabra")); // C++ 11

It is a thin and efficient wrapper around a raw pointer (No overheads !). Roughly speaking:

```
template <typename T>
class unique_ptr{
public:
        unique_ptr(const T & data): data(data) {}  // Ctor
        ~unique_ptr() {delete data;}  // Managed object is deleted when unique_ptr dies !
        ...   // Also move Ctor and move assignment, but not copy !
              // Also operator->, operator*, get(), release() ...
private:
        T * data;      // Pointer to the managed object
};
```

unique_ptr manages a heap object



unique_ptr manages a heap object (can also hold **nullptr** == empty **unique_ptr**)

While **unique_ptr** lives, the managed object lives

When **unique_ptr** dies, its destructor deletes the managed object by **delete**

unique_ptr has the size of a *raw pointer* (typically 8 bytes)

unique_ptr is as efficient as raw pointer, no size or performance overheads !

unique_ptr can be *moved* but not *copied*

Using heap with unique_ptr

```
void fun(){
	unique_ptr<string> u = make_unique<string>("Some text");
	..
	// The string object is deleted here by the unique_ptr destructor!
}   // The closing brace: u runs out of scope here

class A{
public:
	A(const char * s) : uS(new std::string(s)) {}   // Ctor
	...
	// No Destructor. The managed object is deleted automatically !
private:
	unique_ptr<string> uS;  // When object of class A dies, Dtor of uS is called
};
// No more delete operators anywhere ! Managed objects die together with uniqie_ptr !
```

What not to do !

```
string *pS = new string("Maria Traydor");  // Created a heap object  with new !
unique_ptr<string> uS1(pS);  // Created a unique_ptr out of it
```

Now **uS** has exclusive ownership of the heap object !

DON'T DO THIS:

```
delete pS;   // Wrong ! unique_ptr takes care of it ! Double delete !
unique_ptr<string> uS2(pS);  // Wrong ! Creating uS2 for the same object !!!
```

Cannot create 2 **unique_ptr** objects from a single heap object !!! Double delete !
make_unique makes it safer, no explicit **new**, no raw pointers:

```
auto uS1 = make_unique<string>("Maria Traydor");
```

Using unique_ptr 1

```
auto u = make_unique<string>("Maria Traydor");
```

What can we do with it ? Use it as a normal pointer!
Operators ***u, u->** are defined. ***u** is the underlying **string** object.

```
cout << "*u = " << *u << endl;  // Dereferencing
*u = "Nel Zelpher";  // Change the string (NOT pointer !)
cout << "*u = " << *u << endl;  // Print the string again !
cout << " u->size() = " << u->size() << endl;  // Call method, operator-> is overloaded
cout << " (*u).size() = " << (*u).size() << endl;  // The same !, operator* is overloaded
```

Check that **unique_ptr** object has a managed object (i.e. is not **nullptr**):

```
if (u)
      ...
```

Using unique_ptr 2

```
auto u = make_unique<string>("Maria Traydor");

u.reset();                      // Force delete the managed object (if any), u becomes nullptr
u = nullptr;                    // The same
string *p1 = u.get();           // Get the raw pointer (Don't delete it !)
delete p1; // Error !!!
string *p2 = u.release();       // Release ownership of the managed object
delete p2;                      // Now you must delete it !
```

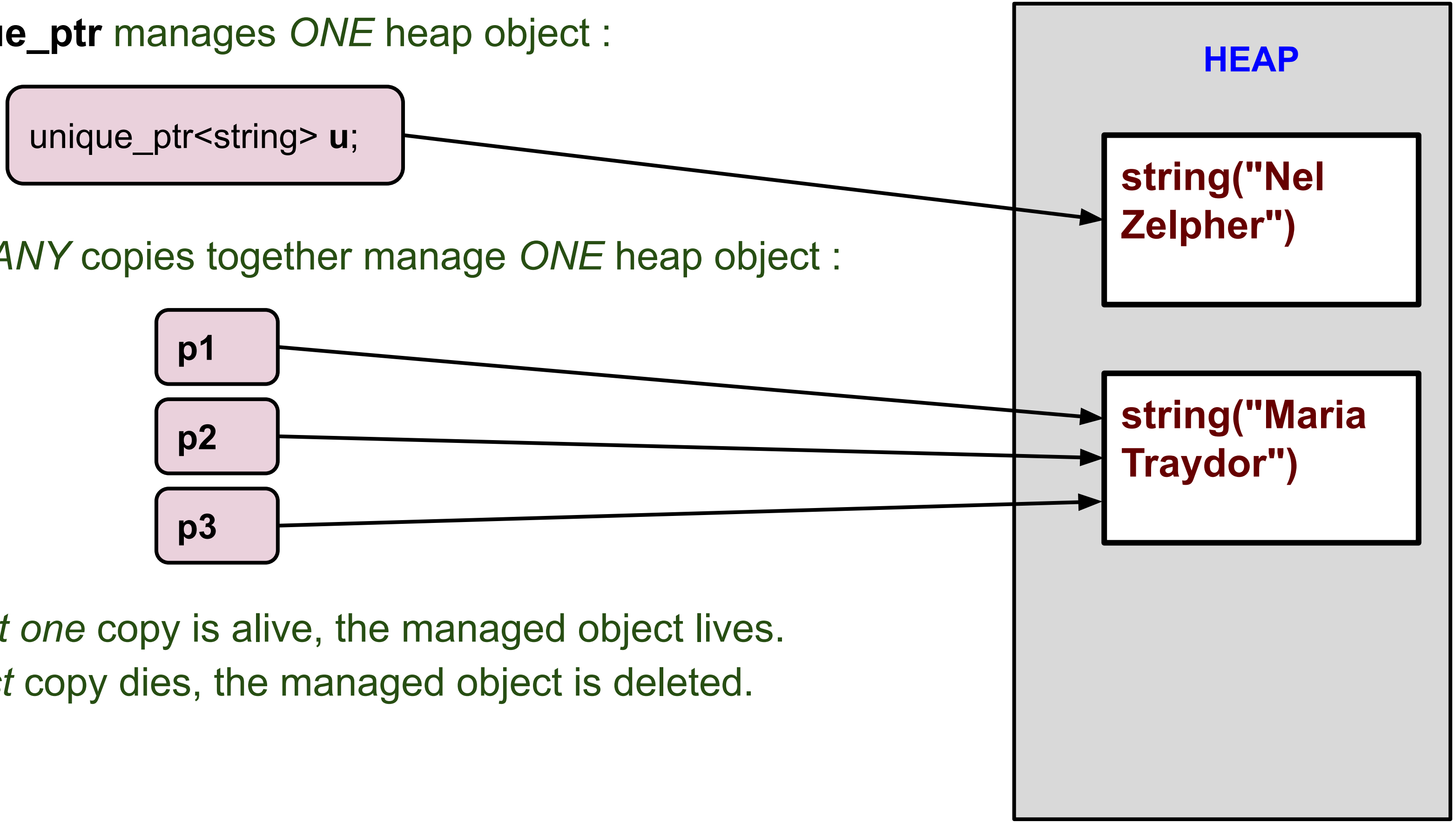
unique_ptr cannot be copied but can be moved !

```
auto u2 = u;                    // Error !!!
auto u2 = move(u);              // OK ! Ownership transferred to u2, u becomes nullptr!
```

move transfers ownership of the managed object to another **unique_ptr** object.
The old object **u** is reset (set to **nullptr**).
Extra slides: creating sources (factories) and sinks with unique_ptr

Smart pointer which can be copied ?

ONE **unique_ptr** manages *ONE* heap object :

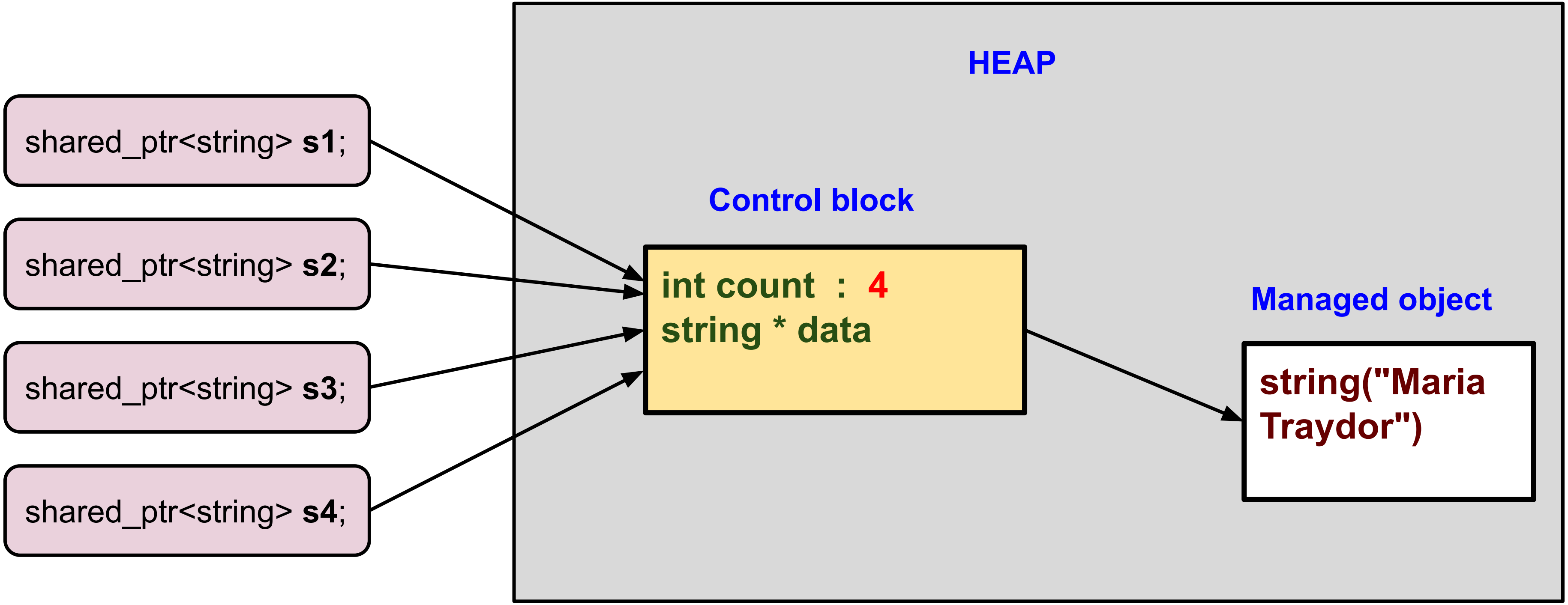


We want: *MANY* copies together manage *ONE* heap object :

While *at least one* copy is alive, the managed object lives.

When *the last* copy dies, the managed object is deleted.

shared_ptr concept : Reference Counting in C++



While *at least one* copy is alive, the managed object AND the control block live.
When *the last* copy dies, they are BOTH deleted (*reference counting* pattern).

Creating shared_ptr

Creating **shared_ptr** :

```
shared_ptr<Tjej> s1 = make_shared<Tjej>("Maria Traydor");
auto s2 = make_shared<Tjej>("Nel Zelpher");   // Preferred, beautiful !
shared_ptr<Tjej> s3(new Tjej("Sophia Esteed"));  // Ugly, new without delete !
```

You can also correctly convert **unique_ptr** to **shared_ptr** (don't forget **move** !)

```
auto u = make_unique<Tjej>("Mirage Koas");
shared_ptr<Tjej> s4(move(u));    // u is nullified, s4 takes over the object
```

shared_ptr can be both copied and moved:

```
auto s5 = s1;
auto s7 = move(s3); // Now s3 becomes nullptr
s3 = s2;  // Copy pointer, not value

*s1 = *s3;  // Copy value, not pointer!
```

Using shared_ptr

Use it as a normal pointer!

```
auto s = make_shared<string>("Kajsa");
cout << "*s = " << *s << endl;
*s = "Eva";   // Change the value, not ptr !
cout << "*s = " << *s << endl;
cout << "s->size() = " << s->size() << endl;
```

Other things you can do:

```
s.reset();   // Resets s, does not delete the managed object unless it's the last copy
s = nullptr;  // The same
cout << s.use_count() << endl;   // Number of copies in existence
cout << s.unique() << endl;        // Is this the only copy ?
string *str = s.get();                // Get a raw pointer
if (s)                               // Check that s is valid (not nullptr)
    ...
```

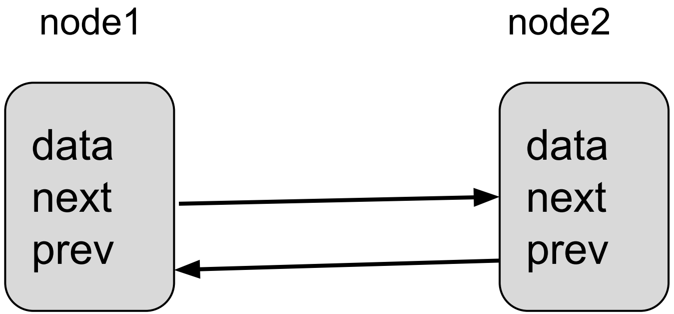
shared_ptr philosophy

- **shared_ptr** Introduces some overheads (control block), don't create 10^9 of them!
- **shared_ptr** feels very similar to Java/Python/.... objects
- Copying **shared_ptr** copies the reference, not the data
- However it uses *reference count*, not full Java-style garbage collection!
- Memory leak is still possible from *cyclic reference*
- The same principle (*reference count*) is used by **cv::Mat**
- *Objects in heap*: no matter where **shared_ptr** or **unique_ptr** is (stack, class fields), the *managed object* is always in the heap! This is good for large managed objects!
- BTW: Most C++ containers (e.g. **vector**) manage their own memory and keep their data in the heap. Exception : **array**.
- **shared_ptr<vector>** is a good combination: container with shared access and no copying.

Can shared_ptr cause a memory leak ?

Suppose we want a double-linked list of nodes:

```
struct Node{
    Node(const string & data) : data(data) {}
    string data;
    shared_ptr<Node> next;      // Next node
    shared_ptr<Node> prev;     // Previous node
};
```



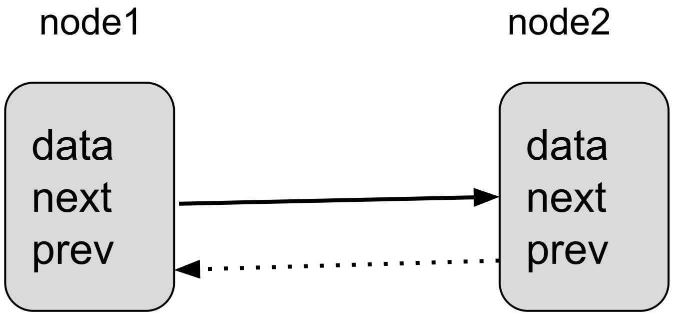
shared_ptr cyclic reference ! Memory leak !!!

Nodes are never deleted as they keep each other alive!

Solution: weak_ptr

Let us rewrite our node like this:

```
struct Node{
    Node(const string & data) : data(data) {}
    string data;
    shared_ptr<Node> next;      // Next node
    weak_ptr<Node> prev;        // Previous node : weak_ptr !!!!
};
```



No more **shared_ptr** cyclic reference ! No more memory leak !!!

Extra slides : Using weak_ptr

Exceptions

Exception interrupts the flow of the program

```
if (a >= 0) throw
        std::runtime_error("The user is an idiot !");   // No "new" here !!! Important !
```

Exception can be caught (**std::runtime_error** is a subclass of **std::exception**)

```
try {
        ...
} catch (const std::exception & e) {
        cerr << e.what() << endl;
}
```

In the exception is NOT caught, the program terminates

Re-throw and noexcept

Re-throw the exception just caught:

```
catch (...) { // "..." means "Catch everything"
        cout << "Caught something !!! " << endl;
        throw ;  // Re-throw the same exception again
}
```

noexcept : Specifies that a function/method does not throw exceptions.
It includes the exceptions *passing through* (f1() -> f2() -> f(3)).

```
int add(int a, int b) noexcept {
        return a+b;
}
```

noexcept allows for better optimization. If the function throws anyway, it cannot be caught and the program terminates. Always used for move Ctors/assignment.

Extra Slides on exceptions: Your own exception classes etc.

std::pair : container with 2 elements of different types

pair<A, B> is a simple container with two fields of different types T, U:

```
template <typename T, typename U>
struct pair{
        ...
        T first;
        U second;
};

pair<string, int> p1("Maria Traydor", 19);
auto p2 = make_pair(string("Nel Zelpher"), 23); // Easy to get types wrong !
auto p3 = make_pair<string, int>("Nel Zelpher", 23);   // Better !
auto p4 = pair<string, int>("Nel Zelpher", 23);     // Basically same result
pair<string, int> p5;
p5 = {"Sophia Esteed", 19};       // Assign with a list
cout << p1.first << " : " << p1.second << endl;
```

Read it yourself : std::tuple

std::optional (C++ 17) : either an object or an empty container

Creating **optional**:

optional<string> o1; // Empty optional

optional<string> o2{"Arboga 10.2%"}; // Optional with a string

Using **optional**:

o2.has_value() Does **o2** have value? **false** if o2 is empty

o2.value() Value of **o2**, throws **bad_optional_access** if empty

if (o2) ... Check that **o2** is not empty

o2.value_or("Default string") Value, or default value if empty

More options:

o2.reset(); // Clear **o2** (make it empty)

o2 = nullopt; // The same

o2 = make_optional<string>("Spendrups"); // Create optional, don't copy/move string

Note : **unique_ptr** can be used instead of **optional** (**nullptr** for empty value)

std::any (C++ 17) : object of any type (or empty)

Container of dynamic type in C++ ! Can be assigned object of (almost) any type !

```
any a;                        // Create an empty any object
a = 17;                       // a becomes int
a = string("Reimi Saionji"); // a becomes string
a.reset();                    // Make a empty
```

Using **any**:

a.type()	Type of a (**std::type_info** object), or void for empty
a.type().name()	Name of the type (not really verbose !)
a.type() == typeid(int)	Compare (at runtime) to a known type
a.has_value()	Does a contain anything? **false** for empty
any_cast<int>(a)	Retrieve the int value, throws **bad_any_cast** if wrong type

Note: The types must be *strictly* identical ! No **int**/**double** or **int**/**long** conversion !

enum class and enum

enum class : C++ enumerated type:

```
enum class Color {red, green, blue, cyan, magenta, yellow, orange};
Color a = Color::magenta;  // Create a variable
int b = static_cast<int>(a);    // Need explicit cast to convert to int
switch (a) {          // Use in switch
    case Color::green:
    ...
```

Note: constants are scoped by **Color::**, no name conflicts !

enum : C enum type

```
enum ColorE {red, green, blue, cyan, magenta, yellow, orange};
ColorE a = magenta;   // Create a variable, names leak, bad !
int b = a;                        // Implicit conversion to int, dangerous !
```

Do not use this in C++, except maybe *inside* class definition

Extra slides : enum

Library of the day : Eigen (Example 5_6)

Eigen is a header-only C++ linear algebra library (can optionally use lapack)

Plays a role similar to *numpy*

```
Eigen::MatrixXd m(2, 3); // Double matrix : 2 rows, 3 cols
m << 1, 2, 3, 4, 5, 6; // Provide values (overloaded operators << and ,)

Eigen::VectorXd v(3);  // Column double 3-vector
v << 1, 0, -1;

cout << "m = " << m << endl;
cout << "v = " << v << endl;
cout << "m*v = " << m*v << endl;    // Multiply matrix by vector
```

- Matrices are *copied* (unlike in OpenCV)
- Don't use fixed-size matrices like **Matrix4d**, alignment issues!
- **ArrayXXd** is similar to `MatrixXd`, `but with element-wise operator` *****
- `Contains diagonalization, SVD, ...`

Type conversions (type casts)

Implicit conversions:
Primitive types, pointers to **void ***, pointer upcast, constructors, cast operators

C++-style casts. Conversion from type B to type A:
B b;
const_cast<A>(b) // Remove const from a pointer or reference
static_cast<A>(b) // Various type conversions
dynamic_cast<A>(b) // Safe polymorphic cast (pointer or reference)
reinterpret_cast<A>(b) // Reinterpret memory bytes as different type

C-style casts:
(A)b // Roughly speaking **const_cast, static_cast, reinterpret_cast**
A(b) // In that order

Implicit conversions : Dangerous !

Implicit conversions:

```
A a;
B b;
b = a;           // A is converted to B on assignment
myfunc(a);       // Expects argument of type B, type A provided instead
```

Primitive types:

```
float a = 777;   // Possible loss of accuracy
int b = 3.5;     // Loss of accuracy
char c = 1987;   // Loss of higher bytes (Warning !)
```

Other types:

```
void * pV = &a;            // Cast any pointer to void *
string s = "Phoenix";      // Constructor : cast const char[8] to string
bool b(cout);              // Cast operator: cast ostream to bool
```

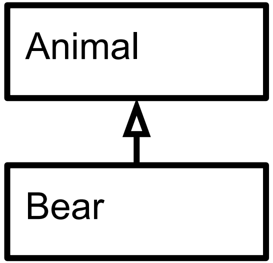
const_cast: Remove (cast away) const from ptrs, refs

Converts **const type *** to **type *** or **const type &** to **type &** :

```
int a = 17;
const int & crA = a;
int & rA = const_cast<int &>(crA);    // Remove const
rA = 20;
cout << "a = " << a << endl;              // Prints 20

double b = 1.1;
const double * cpB = &b;
double * pB = const_cast<double *>(cpB);    // Remove const
*pB = 2.2;
cout << "b = " << b << endl;              // Prints 2.2
```

C++ Polymorphism: Upcasts and Downcasts



class Animal {...};
class Bear: public Animal {...};

Bear inherits **Animal**

Upcasts: Every **Bear** is an **Animal** ! Safe and implicit.

Bear & to **Animal &**, **Bear *** to **Animal ***

Downcasts: Not every **Animal** is a **Bear** !

Animal & to **Bear &**, **Animal *** to **Bear ***

Requires **static_cast** or **dynamic_cast** !
Only works if our **Animal &** or **Animal *** points to a **Bear** object !

static_cast: All "normal" casts

1. Implicit conversion made explicit (and remove warnings)

string s = static_cast<string>("Idiot !");

2. **enum class** <-> **int**

int i = static_cast<int>(Num::Four);

3. **void *** to any pointer (No checks !)

4. Reference/pointer downcast: **Base *** to **Derived ***, **Base &** to **Derived &**. No checks!

Does not check that the object is of **Derived** class, unsafe !

```
Derived d;
Base & rB = d;
Base * pB = &d;
Derived & rD =  static_cast<Derived &> (rB);    // Downcast
Derived * pD =  static_cast<Derived *> (pB);    // No checks  !
rD.print();                                     // Prints "Derived" twice
pD->print();
```

dynamic_cast: Pointer/reference downcast with checks

Like previous example, but with checks at runtime (slower):

```
Derived d;
Base & rB = d;
Base * pB = &d;
Derived & rD =  dynamic_cast<Derived &> (rB);    // Downcast
Derived * pD =  dynamic_cast<Derived *> (pB);    // No checks  !
rD.print();                                      // Prints "Derived" twice
pD->print();
```

throws **bad_cast** (for references) or returns **nullptr** (for pointers) if the type is wrong:

```
Base b2;
Base & rB2 = b2;
Base * pB2 = &b2;
Derived & rD2 = dynamic_cast<Derived &> (rB2);    // throws bad_cast
Derived * pD2 = dynamic_cast<Derived *> (pB2);    // returns nullptr
```

reinterpret_cast, C-style casts

reinterpret_cast interprets memory bytes as a different type
Converts pointers of different types (e.g. **int *** to **double ***) with no checks.

```
int i = 17;
int *pI = &i;     // Pointer
long long j = reinterpret_cast<long long>(pI);
```

C-style casts (Bad style, IMHO OK for primitive types):
Roughly speaking: **const_cast**, **static_cast** or **reinterpret_cast** in this order.

```
char c = (char) 2017;
int i = (int) 13.456789;
Derived & rD = (Derived &) rB;
Derived * pD = (Derived *) pB;
```

Extra slides: unique_ptr, shared_ptr and polymorphism

Thank you for your attention !

unique_ptr and source (factory) functions

Source (factory) creates a heap object and returns **unique_ptr**

```
unique_ptr<Tjej> factory1(const string & name){
    return make_unique<Tjej>(name);  // No need for explicit move here
}
```

```
unique_ptr<Tjej> factory2(const string & name){
    unique_ptr<Tjej> upT = make_unique<Tjej>(name);
    /// Do something with upT
    return move(upT);   // Will work without move also
}
```

Usage:

```
    auto upT1 = factory1("Nel Zelpher");
    auto upT2 = factory2("Claire Lasbard");
    ...
}   // upT1, upT2 and managed objects are destroyed HERE !
```

unique_ptr and sinks (consumers)

Sink (consumer) eats **unique_ptr** and destroys it (and the managed object)

Argument is passed *by value* (NOT reference !) using **move** :

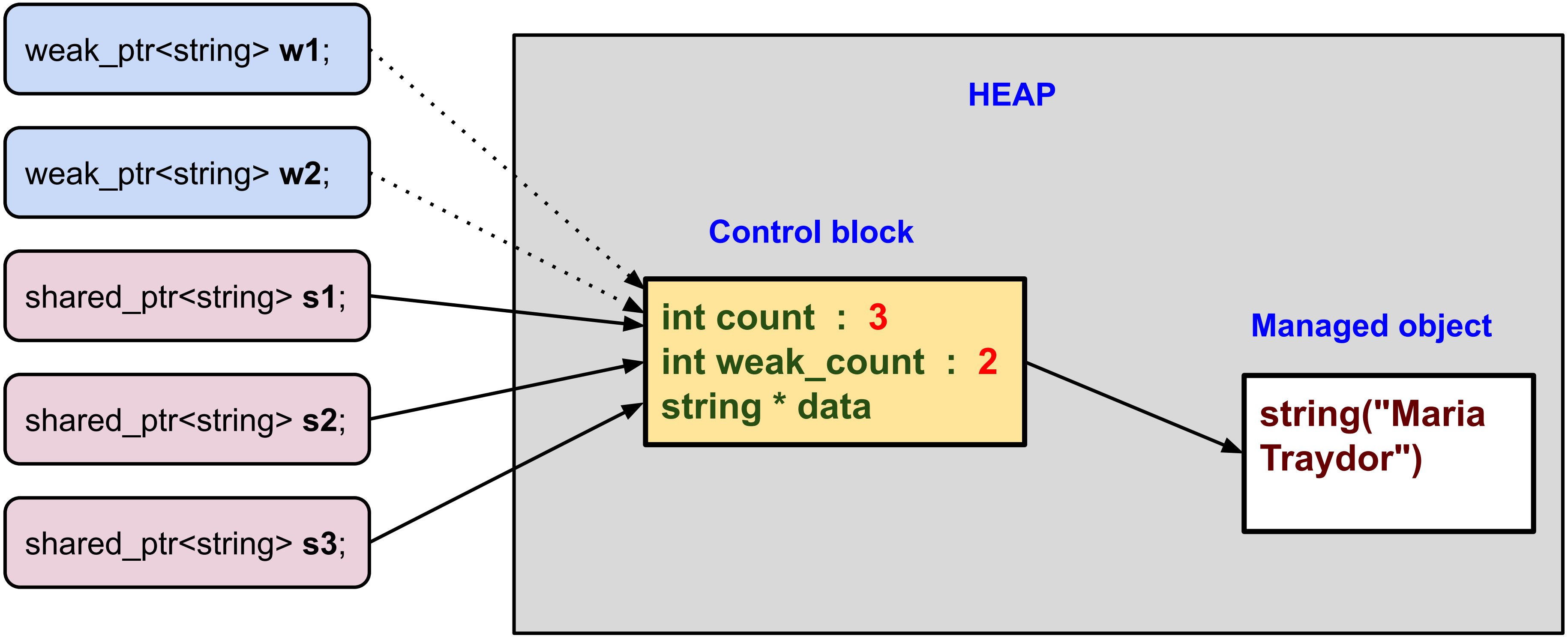
```
void sink(unique_ptr<Tjej> upT){     // By value !!! NO ref ! MOVED here !
    // upT is local in this function
    cout << "Sink: name = " << upT->getName() << endl;
    // Now upT and the managed object are destroyed as they go out of scope !
}
```

Usage:

```
    auto upT = make_unique<Tjej>("Sophia Esteed");
    sink(move(upT));                               // Move to sink

    // The managed object is destroyed by now and upT == nullptr
    ...
}  // Nothing happens here !
```

weak_ptr concept: a weak reference to a shared_ptr



When the last **shared_ptr** dies, the managed object is deleted, the control block stays !

When the last **weak_ptr** dies, the control block is deleted !

Using weak_ptr

Create a **weak_ptr** out of a **shared_ptr** :

```
shared_ptr<string> s = make_shared<string>("Maria Traydor");
weak_ptr<string> w = s;
```

Restore **shared_ptr** from a **weak_ptr** (creates one more **shared_ptr** copy):

```
if (! w.expired() ) {                          // Check if w is expired
    shared_ptr<string> s = w.lock();       // Returns nullptr if expired
    ...
}
```

weak_ptr is *expired* when the last **shared_ptr** dies and the managed object is deleted

weak_ptr can be reset, copied and moved, but cannot be dereferenced:

```
*w              // Error !!!
w->size()       // Error !!!
```

weak_ptr can be also used for the *weak reference* pattern:
caches, observers (like **WeakReference** in Java)

Objects of any type can be thrown and caught

```
try {
        throw 17;                          // int
        throw (unsigned)17;        // unsigned, not int !
} catch (int i) {
        cout << "int exception " << i << endl;
} catch (double d) {
        cout << "double exception " << d << endl;
} catch (const string & s) {
        cout << "string exception " << s << endl;
} catch (const char * cS) {        // Will catch string literals
        cout << "char * exception " << cS << endl;
} catch (...) {                    // Default
        cout << "Unknown exception" << endl;
}
```

NEVER EVER use **new** in **throw** !!!! Memory leak !!!

But the standard class is std::exception and subclasses

throw runtime_error("Earthquake"); // std::string parameter !
throw logic_error("Earthquake");
// invalid_argument, domain_error, length_error, out_of_range
// range_error, overflow_error, underflow_error

Define your own exception: Inherit **runtime_error** (simplest), or implement **std::exception**
what() message is printed if not caught (**std::exception** subclasses only !)

```
struct DiamondException : public std::runtime_error{
    explicit DiamondException(const std::string & s) :
         runtime_error("Diamond: " + s) {}
};

struct SapphireException : public std::exception{
    const char * what() const noexcept override {
        return "Al2O3";
    }
};
```

Exceptions and function calls

```
void f3() {
	int a;
	throw runtime_error("HAHA");
}
void f2() {
	string s("Local String"); f3();
}
void f1(){ f2(); }
void main() {
	try {
		f1();   // Calls f1() -> f2() -> f(3)
	} catch (...) { /* Some code*/   }
}
```

Exception thrown in **f3** goes right through **f2** and **f1** and is caught in **main**.

Any local variables of **f3**, **f2**, **f1** are properly deleted (*stack unwinding*)

enum (class) : specify numerical values

```
enum Color {red = 17, green, blue, cyan, magenta, yellow, orange};
cout << red << " " << green << " " << blue << " " << cyan << " " << magenta <<
      " " << yellow << " " << orange << endl;
```

```
17 18 19 20 21 22 23
```

Danger !

```
enum class Color {red, green, blue, cyan = 1, magenta, yellow, orange};
```

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

Values are repeated !!!

Using **enum** for **int** constants, anonymous unscoped **enum**

(Note: considered to be bad style, use **constexpr** instead)

```
enum {OK = 0, FILE_NOT_FOUND = 1234, BAD_DATA = 1235, IO_ERRROR = 1236};
int i = readData();
switch (i) {
      ...
```

Enum underying type

You can choose the underlying type of **enum**

```
enum Color1 : int {red, green, blue, cyan , magenta, yellow, orange};
enum class Color2 : unsigned char {red, green, blue, cyan , magenta, yellow, orange};
enum class Color3 : long long {red, green, blue, cyan , magenta, yellow, orange};
sizeof(Color1) == 4
sizeof(Color2) == 1
sizeof(Color3) == 8
```

The default type is **int** (4 bytes)

You can use **unsigned char** (1 byte) to save memory !

unique_ptr and polymorphism (upcasts, downcasts) ?

Bear is a subclass of **Animal**. Can we do something like this ???

```
auto upB = make_unique<Bear>("Teddy", 7);
auto upA = dynamic_cast<unique_ptr<Animal> >(upB);
```

unique_ptr and polymorphism (upcasts, downcasts) ?

Bear is a subclass of **Animal**. Can we do something like this ???

```
auto upB = make_unique<Bear>("Teddy");
auto upA = dynamic_cast<unique_ptr<Animal> > (upB);   // Wrong !!!
```

NO !!! This would be like copying **unique_ptr** !
You DO NOT upcast/downcast **unique_ptr** !

The correct way: use ***upB** as a reference or **upB.get()** as a raw pointer:

```
Animal & rA = *upB;              // Reference upcast. Good !
Animal * pA = upB.get();         // Pointer upcast. Ugly ! Don't delete pA !
```

Or downcast with **dynamic_cast** :

```
unique_ptr<Animal>(new Bear("Teddy"));   // Animal unique_ptr which holds a Bear
Bear & rB = dynamic_cast<Bear &>(*upA);        // Reference downcast. Good !
Bear * pB = dynamic_cast<Bear *>(upA.get()); // Pointer downcast. Ugly ! Don't delete pB !
```

shared_ptr and polymorphism: upcasts and downcasts

```
auto sB = make_shared< Bear>("Teddy");   // Create a shared_ptr<Bear> object

cout << "Ref upcast :" << endl;
Animal & rA = *sB;
rA.talk();

cout << "Raw ptr upcast :" << endl;
Animal * pA = sB.get();                        // Get the raw Bear * ptr
pA->talk();

cout << "shared_ptr upcast :" << endl;
shared_ptr<Animal> sA = sB;                    // Implicit upcast
sA->talk();

cout << "shared_ptr downcast :" << endl;
shared_ptr<Bear> sB1 =  static_pointer_cast<Bear>(sA);     // No checks !
shared_ptr<Bear> sB2 =  dynamic_pointer_cast<Bear>(sA);    // Checks. Safe.
sB1->talk();
sB2->talk();
```

title

text