Modern C++ for Computer Vision and Image Processing

Lecture 6: Modern C++ Classes

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Create new types with classes and structs

- Classes are used to **encapsulate data** along with methods to process them
- Every `class` or `struct` defines a new type
- **Terminology**:
  - **Type** or **class** to talk about the defined type
  - A variable of such type is an **instance of class** or an **object**
- Classes allow C++ to be used as an **O**bject **O**riented **P**rogramming language
- `string`, `vector`, etc. are all classes

http://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines#c-classes-and-class-hierarchies

C++ Class Anatomy

class.cpp class.cpp

```
1   class MyNewType {
2   public:
3     MyNewType();
4     ~MyNewType();
5
6   public:
7     void MemberFunction1();
8     void MemberFunction2() const;
9     static void StaticFunction();
10
11  public:
12    MyNewType &operator+=(const MyNewType &other);
13    std::ostream &operator<<(std::ostream &os, const MyNewType &obj);
14
15  private:
16    int a_;
17    std::vector<float> data_;
18    MyType2 member_;
19  };
```

Class Definition

Constructors and Destructors

Member Functions

Operators

Data Members

Class Glossary

- **Class** Definition.
- **Class** Implementation.
- **Class** data members.
- **Class** Member functions.
- **Class** Constructors.
- **Class** Destructor.
- **Class** setters.
- **Class** getters.
- **Class** operators.
- **Class** static members.
- **Class** Inheritance.

Classes syntax

- Definition starts with the keyword `class`
- Classes have **three access modifiers**: `private`, `protected` and `public`
- By default everything is `private`
- Classes can contain data and functions
- Access members with a `"."`
- Have two types of **special functions**:
  - **Constructors**: called upon **creation** of an instance of the class
  - **Destructor**: called upon **destruction** of an instance of the class
- `GOOGLE-STYLE` Use `CamelCase` for class name

https://google.github.io/styleguide/cppguide.html#Type_Names

What about structs?

- Definition starts with the keyword `struct`:

```
1 struct ExampleStruct {
2   Type value;
3   Type value;
4   Type value;
5   // No functions!
6 };
```

- `struct` is a `class` where everything is `public`
- `GOOGLE-STYLE` Use `struct` as a **simple data container**, if it needs a function it should be a `class` instead

https://google.github.io/styleguide/cppguide.html#Structs_vs._Classes

Always initialize structs using braced initialization

```
1  #include <iostream>
2  #include <string>
3  struct NamedInt {
4    int num;
5    std::string name;
6  };
7
8  void PrintStruct(const NamedInt& s) {
9    std::cout << s.name << " " << s.num << std::endl;
10 }
11
12 int main() {
13   NamedInt var{1, std::string{"hello"}};
14   PrintStruct(var);
15   PrintStruct({10, std::string{"world"}});
16   return 0;
17 }
```

Data stored in a class

- Classes can store data of any type
- `GOOGLE-STYLE` All data must be `private`
- `GOOGLE-STYLE` Use `snake_case_` with a trailing `"_"` for `private` data members
- Data should be **set in the Constructor**
- **Cleanup data in the Destructor** if needed

https://google.github.io/styleguide/cppguide.html#Access_Control

https://google.github.io/styleguide/cppguide.html#Variable_Names

Constructors and Destructor

- Classes always have **at least one Constructor** and **exactly one Destructor**
- Constructors crash course:
  - Are functions with no **explicit** return type
  - Named exactly as the class
  - There can be many constructors
  - **If there is no explicit constructor an implicit default constructor will be generated**
- Destructor for class `SomeClass`:
  - Is a function named `~SomeClass()`
  - Last function called in the lifetime of an object
  - Generated automatically if not explicitly defined

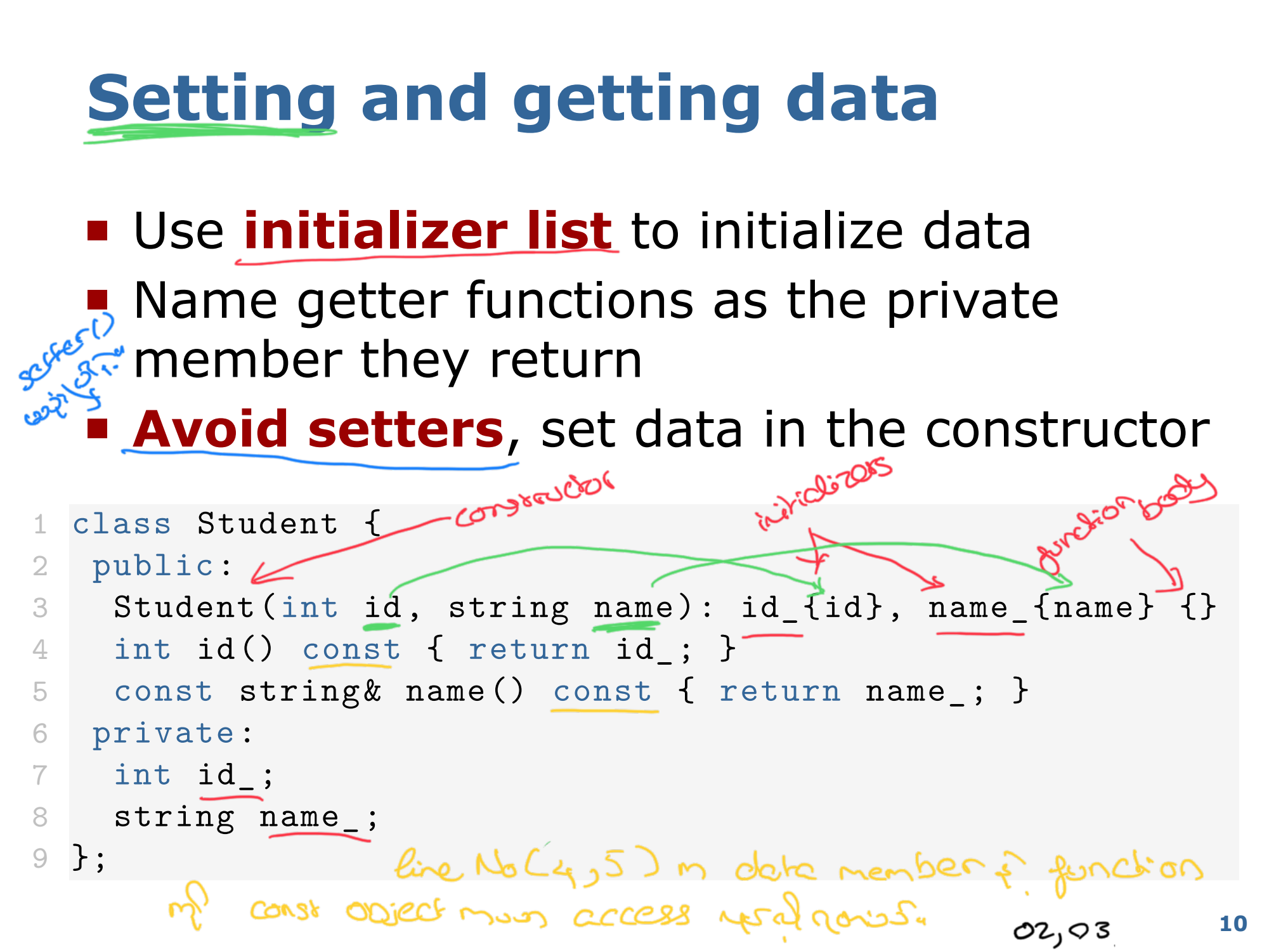
Many ways to create instances

```
1  class SomeClass {
2   public:
3    SomeClass();                    // Default constructor.
4    SomeClass(int a);               // Custom constructor.
5    SomeClass(int a, float b);      // Custom constructor.
6    ~SomeClass();                   // Destructor.
7  };
8  // How to use them?
9  int main() {
10   SomeClass var_1;                  // Default constructor
11   SomeClass var_2(10);              // Custom constructor
12   // Type is checked when using {} braces. Use them!
13   SomeClass var_3{10};              // Custom constructor
14   SomeClass var_4 = {10};           // Same as var_3
15   SomeClass var_5{10, 10.0};        // Custom constructor
16   SomeClass var_6 = {10, 10.0};     // Same as var_5
17   return 0;
18 }
```

Setting and getting data

- Use **initializer list** to initialize data
- Name getter functions as the private member they return
- **Avoid setters**, set data in the constructor

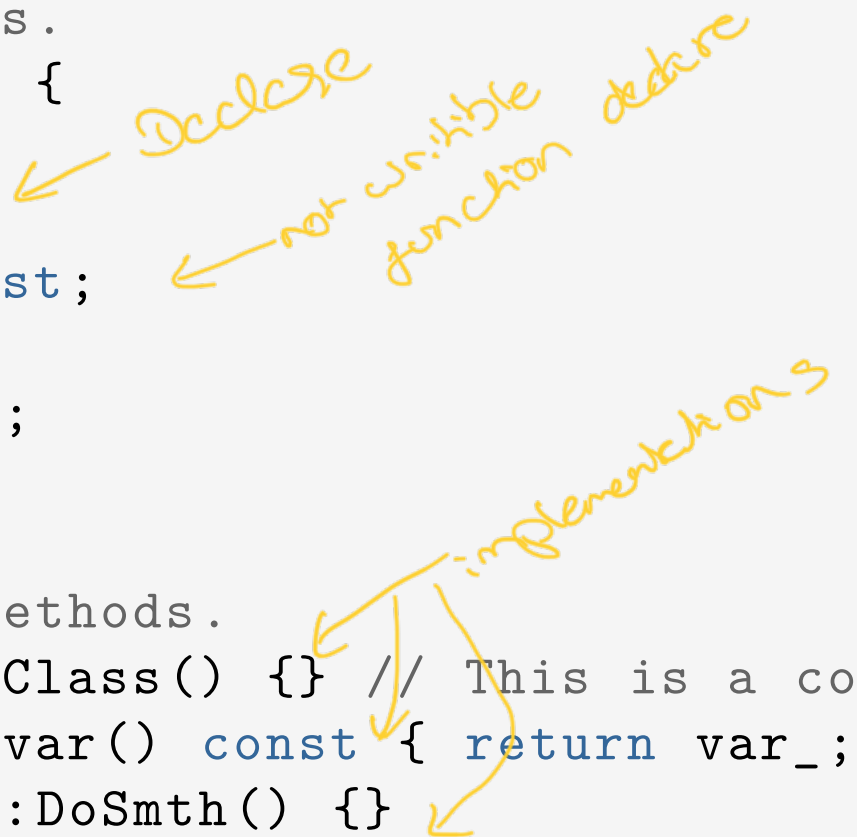
```
1  class Student {
2   public:
3    Student(int id, string name): id_{id}, name_{name} {}
4    int id() const { return id_; }
5    const string& name() const { return name_; }
6   private:
7    int id_;
8    string name_;
9  };
```



Declaration and definition

- Data members belong to declaration
- Class methods can be defined elsewhere
- Class name becomes part of function name

```
1  // Declare class.
2  class SomeClass {
3   public:
4    SomeClass();
5    int var() const;
6   private:
7    void DoSmth();
8    int var_ = 0;
9  };
10 // Define all methods.
11 SomeClass::SomeClass() {} // This is a constructor
12 int SomeClass::var() const { return var_; }
13 void SomeClass::DoSmth() {}
```



Always initialize members for classes

- C++ 11 allows to initialize variables in-place
- Do not initialize them in the constructor
- No need for an explicit default constructor

```
1 class Student {
2  public:
3   // No need for default constructor.
4   // Getters and functions omitted.
5  private:
6   int earned_points_ = 0;
7   float happiness_ = 1.0f;
8 };
```

- **Note:** Leave the members of `structs` uninitialized as defining them forbids using brace initialization

Classes as modules

- Prefer encapsulating information that belongs together into a class
- **Separate declaration and definition** of the class into header and source files
- Typically, class `SomeClass` is declared in `some_class.hpp` and is defined in `some_class.cpp`

Const correctness

- `const` after function states that this function **does not change the object**
- Mark all functions that **should not** change the state of the object as `const`
- Ensures that we can pass objects by a `const` reference and still call their functions
- Substantially reduces number of errors

Typical const error

```
1  #include <iostream>
2  #include <string>
3  using namespace std;
4  class Student {
5   public:
6    Student(string name) : name_{name} {}
7    // This function *might* change the object
8    const string& name() { return name_;
9   private:
10   string name_;
11 };
12 void Print(const Student& student) {
13   cout << "Student: " << student.name() << endl;
14 }
```


```
1  error: passing "const Student" as "this" argument
       discards qualifiers [-fpermissive]
2     cout << "Student: " << student.name() << endl;
3                                          ^
```

Intuition lvalues, rvalues

- Every expression is an `lvalue` or an `rvalue`
- `lvalues` can be written on the **left** of assignment operator (`=`)
- `rvalues` are all the other expressions
- Explicit `rvalue` defined using `&&`
- Use `std::move(…)` to explicitly convert an `lvalue` to an `rvalue`

```
1  int a;                  // "a" is an lvalue
2  int& a_ref = a;         // "a" is an lvalue
3                          // "a_ref" is a reference to an lvalue
4  a = 2 + 2;              // "a" is an lvalue,
5                          // "2 + 2" is an rvalue
6  int b = a + 2;          // "b" is an lvalue,
7                          // "a + 2" is an rvalue
8  int&& c = std::move(a); // "c" is an rvalue
```

std::move

`std::move` is used to indicate that an object `t` may be "moved from", i.e. allowing the efficient transfer of resources from t to another object.

In particular, `std::move` produces an `xvalue expression` that identifies its argument `t`. It is exactly equivalent to a `static_cast` to an `rvalue` reference type.

https://en.cppreference.com/w/cpp/utility/move

Important `std::move`

- The `std::move()` is a standard-library function returning an `rvalue` reference to its argument.
- `std::move(x)` means "give me an `rvalue` reference to x."
- That is, `std::move(x)` **does not move** anything; instead, it allows a user to move `x`.

lvalue হলো এমন expression যা memory location কে নির্দেশ করে।
অর্থাৎ যা দ্বারা কোন memory address কে বুঝায়।

rvalue হলো সেই memory address এর data value যাতে
assignment করা যায়। অর্থাৎ যা দ্বারা বুঝায়:

```
int a = 3;
int b = 5;
200 = c;
```

// lvalue error.

Never access values after move

The value after `move` is undefined

```
1  string str = "Hello";
2  vector<string> v;
3
4  // uses the push_back(const T&) overload, which means
5  // we'll incur the cost of copying str
6  v.push_back(str);
7  cout << "After copy, str is " << str << endl;
8
9  // uses the rvalue reference push_back(T&&) overload,
10 // which means no strings will be copied; instead,
11 // the contents of str will be moved into the vector.
12 // This is less expensive, but also means str might
13 // now be empty.
14 v.push_back(move(str));
15 cout << "After move, str is " << str << endl;
```

std::move performance

```
// MyClass has a private member that contains 200 strings
struct MyClass {
  int id_ = 0;
  std::vector<std::string> names_{
      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
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      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
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      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
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      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
      "name", "name",  "name", "name", "name", "name", "name", "name", "name",
      "name", "name",  "name", "name", "name", "name", "name", "name", "name"};
};
```
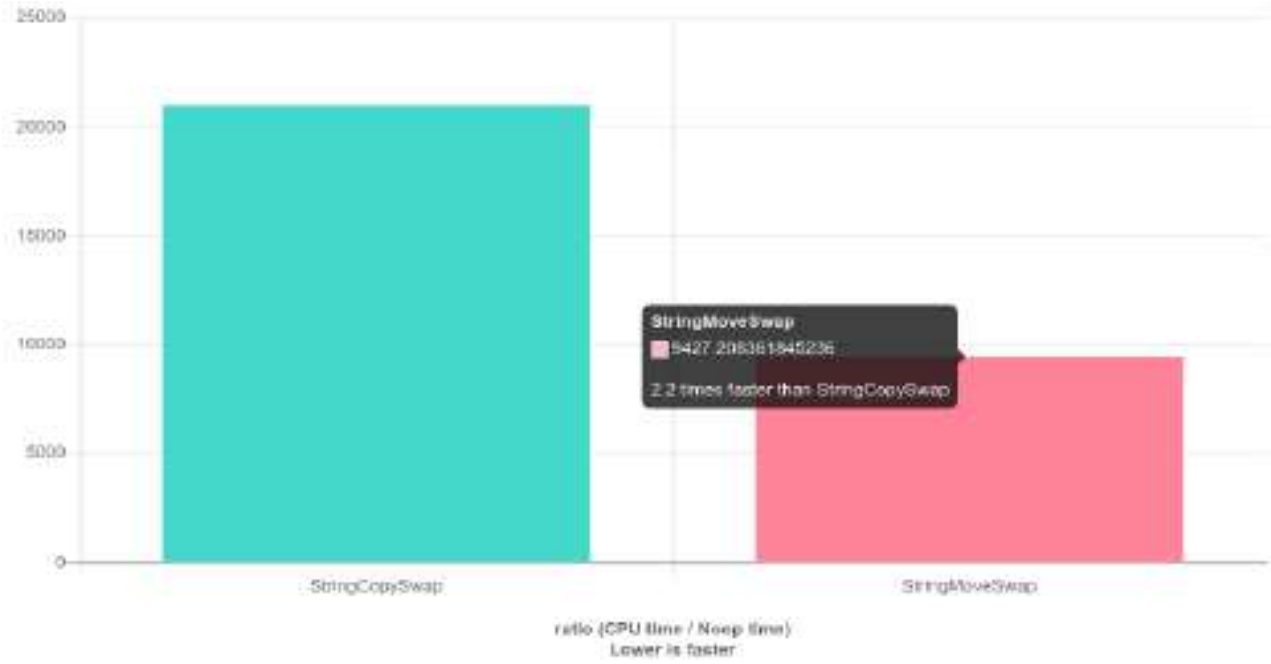

`std::move` performance

```
1  void copy_swap(MyClass& obj1, MyClass& obj2) {
2    MyClass tmp = obj1;  // copy obj1 to tmp
3    obj1 = obj2;         // copy obj2 to obj1
4    obj2 = tmp;          // copy tmp  to obj1
5  }
6
7  void move_swap(MyClass& obj1, MyClass& obj2) {
8    MyClass tmp = std::move(obj1);  // move obj1 to tmp
9    obj1 = std::move(obj2);         // move obj2 to obj1
10   obj2 = std::move(tmp);          // move tmp  to obj1
11 }
```

`std::move` performance



Quick Benchmark available to play:
https://bit.ly/2DFfhko

How to think about std::move

- Think about **ownership**
- Entity **owns** a variable if it deletes it, e.g.
  - A function scope owns a variable defined in it
  - An object of a class owns its data members
- **Moving a variable transfers ownership** of its resources to another variable
- When designing your program think **"who should own this thing?"**
- **Runtime:** better than copying, worse than passing by reference

Custom operators for a class

- Operators are functions with a signature:
  `<RETURN_TYPE> operator<NAME>(<PARAMS>)`
- `<NAME>` represents the target operation, e.g. `>`, `<`, `=`, `==`, `<<` etc.
- Have all attributes of functions
- Always contain word `operator` in name
- All available operators:
  http://en.cppreference.com/w/cpp/language/operators

Example operator <

```
#include <algorithm>
#include <vector>
class Human {
 public:
  Human(int kindness) : kindness_{kindness} {}
  bool operator<(const Human& other) const {
    return kindness_ < other.kindness_;
  }

 private:
  int kindness_ = 100;
};
int main() {
  std::vector<Human> humans = {Human{0}, Human{10}};
  std::sort(humans.begin(), humans.end());
  return 0;
}
```

Example operator <<

```
1  #include <iostream>
2  #include <vector>
3  class Human {
4   public:
5    int kindness(void) const { return kindness_; }
6   private:
7    int kindness_ = 100;
8  };
9
10 std::ostream& operator<<(std::ostream& os, const Human& human) {
11   os << "This human is this kind: " << human.kindness();
12   return os;
13 }
14
15 int main() {
16   std::vector<Human> humans = {Human{0}, Human{10}};
17   for (auto&& human : humans) {
18     std::cout << human << std::endl;
19   }
20   return 0;
21 }
```

Copy constructor

- **Called automatically** when the object is **copied**
- For a class `MyClass` has the signature:
  `MyClass(const MyClass& other)`

```
1 MyClass a;       // Calling default constructor.
2 MyClass b(a);    // Calling copy constructor.
3 MyClass c = a;   // Calling copy constructor.
```

Copy assignment operator

- Copy assignment operator is **called automatically** when the object is **assigned a new value** from an **L**value
- For class `MyClass` has a signature:

```
MyClass& operator=(const MyClass& other)
```

- **Returns a reference** to the changed object
- Use `*this` from within a function of a class to get a reference to the current object

```
1 MyClass a;          // Calling default constructor.
2 MyClass b(a);       // Calling copy constructor.
3 MyClass c = a;      // Calling copy constructor.
4 a = b;              // Calling copy assignment operator.
```

Move constructor

- **Called automatically** when the object is **moved**
- For a class `MyClass` has a signature:
  `MyClass(MyClass&& other)`

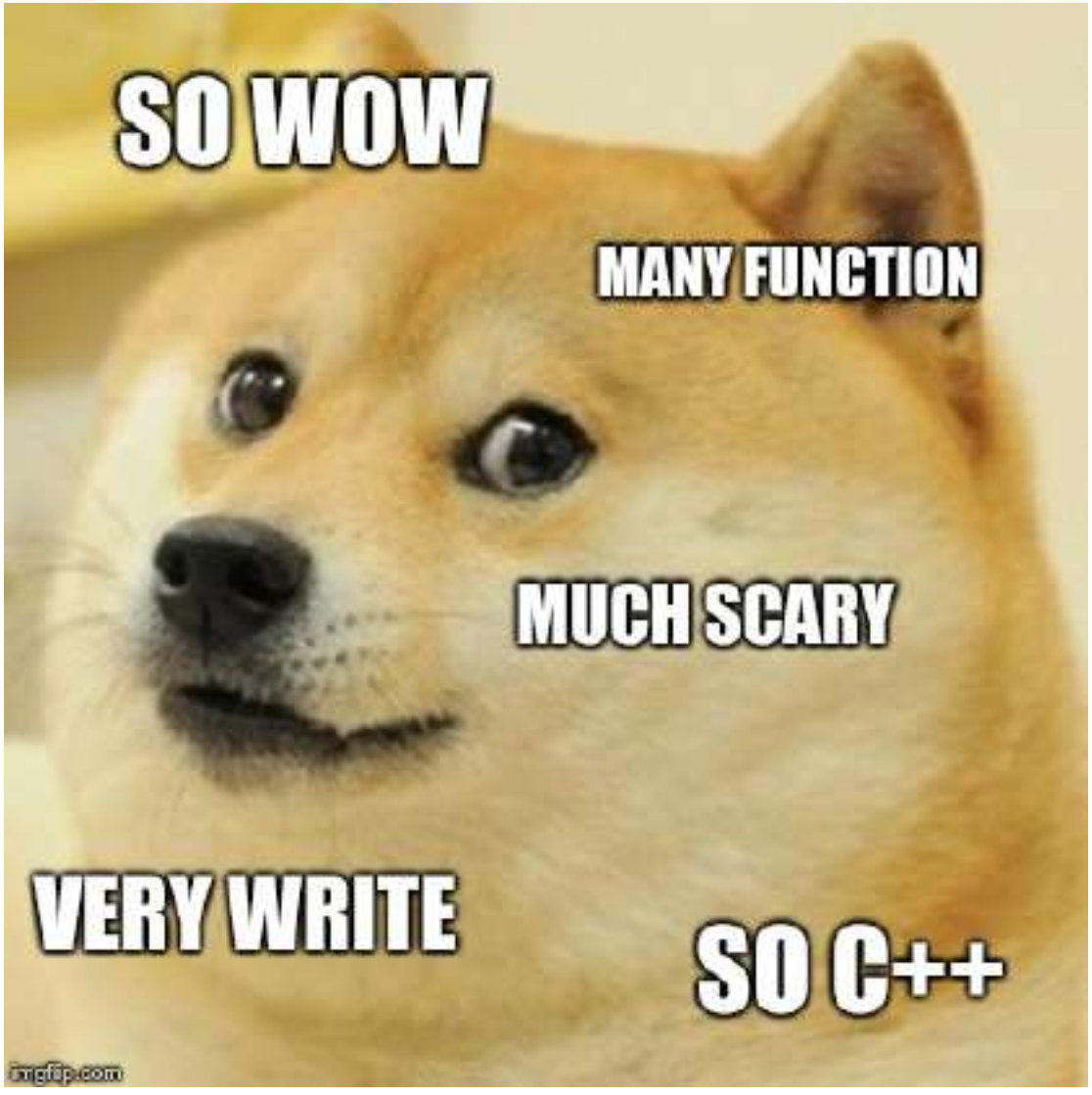
```
1 MyClass a;                    // Default constructors.
2 MyClass b(std::move(a));      // Move constructor.
3 MyClass c = std::move(a);     // Move constructor.
```

Move assignment operator

- **Called automatically** when the object is **assigned a new value** from an **R**value
- For class `MyClass` has a signature:
  `MyClass& operator=(MyClass&& other)`
- **Returns a reference** to the changed object

```
1 MyClass a;                          // Default constructors.
2 MyClass b(std::move(a));            // Move constructor.
3 MyClass c = std::move(a);           // Move constructor.
4 b = std::move(c);                   // Move assignment operator.
```

```cpp
class MyClass {
 public:
  MyClass() { cout << "default" << endl; }
  // Copy(&) and Move(&&) constructors
  MyClass(const MyClass& other) {
    cout << "copy" << endl;
  }
  MyClass(MyClass&& other) {
    cout << "move" << endl;
  }
  // Copy(&) and Move(&&) operators
  MyClass& operator=(const MyClass& other) {
    cout << "copy operator" << endl;
  }
  MyClass& operator=(MyClass&& other) {
    cout << "move operator" << endl;
  }
};

int main() {
  MyClass a;                  // Calls DEFAULT constructor
  MyClass b = a;              // Calls COPY constructor
  a = b;                      // Calls COPY assignment operator
  MyClass c = std::move(a); // Calls MOVE constructor
  c = std::move(b);           // Calls MOVE assignment operator
}
```


SO WOW
MANY FUNCTION
MUCH SCARY
VERY WRITE
SO C++
memegip.com

ဘာတွေလဲ! ဆိုပြီး Constructor တွေအားလုံးကို define မလုပ်ရသေးဘူးလား?

- The constructors and operators will be **generated automatically**
- **Under some conditions…**
- Six special functions for class `MyClass`:
  - `MyClass()`
  - `MyClass(const MyClass& other)`
  - `MyClass& operator=(const MyClass& other)`
  - `MyClass(MyClass&& other)`
  - `MyClass& operator=(MyClass&& other)`
  - `~MyClass()`
- **None** of them defined: **all** auto-generated
- **Any** of them defined: **none** auto-generated

Rule of all or nothing

- Try to define **none** of the special functions
- If you **must** define one of them **define all**
- Use `=default` to use default implementation

```
1 class MyClass {
2  public:
3   MyClass() = default;
4   MyClass(MyClass&& var) = default;
5   MyClass(const MyClass& var) = default;
6   MyClass& operator=(MyClass&& var) = default;
7   MyClass& operator=(const MyClass& var) = default;
8 };
```

Deleted functions

- Any function can be set as `deleted`

```
1 void SomeFunc(...) = delete;
```

- Calling such a function will result in compilation error
- **Example:** remove copy constructors when only one instance of the class must be guaranteed (`Singleton Pattern`)
- Compiler marks some functions deleted automatically
- **Example:** if a class has a constant data member, the copy/move constructors and assignment operators are implicitly deleted

Static variables and methods

Static member variables of a class

- Exist exactly **once** per class, **not** per object
- The value is equal across all instances
- Must be defined in `*.cpp` files(before `C++17`)

Static member functions of a class

- Do not need to access through an object of the class
- Can access private members but need an object
- **Syntax** for calling:

```
ClassName::MethodName(<params>)
```

Static variables : “Counted.hpp”

```
1  class Counted {
2   public:
3    // Increment the count every time someone creates
4    // a new object of class Counted
5    Counted() { Counted::count++; }
6
7    // Decrement the count every time someone deletes
8    // any object of class Counted
9    ~Counted() { Counted::count--; }
10
11   // Static counter member. Keep the count of how
12   // many objects we've created so far
13   static int count;
14 };
```

We can access the `count` public member of the `Counted` class through the namespace resolutions operator: “`::`”

Static variables

```
1  #include <iostream>
2  using std::cout;
3  using std::endl;
4
5  // Include the Counted class declaration and
6  // Initialize the static member of the class only once.
7  // This could be any value
8  #include "Counted.hpp"
9  int Counted::count = 0;
10
11 int main() {
12   Counted a, b;
13   cout << "Count: " << Counted::count << endl;
14   Counted c;
15   cout << "Count: " << Counted::count << endl;
16   return 0;
17 }
```

```cpp
#include <cmath>

class Point {
 public:
  Point(int x, int y) : x_(x), y_(y) {}

  static float Dist(const Point& a, const Point& b) {
    int diff_x = a.x_ - b.x_;
    int diff_y = a.y_ - b.y_;
    return sqrt(diff_x * diff_x + diff_y * diff_y);
  }

  float Dist(const Point& other) {
    int diff_x = x_ - other.x_;
    int diff_y = y_ - other.y_;
    return sqrt(diff_x * diff_x + diff_y * diff_y);
  }

 private:
  int x_ = 0;
  int y_ = 0;
};
```

12

Static member functions

Allow us to define method that does not require an object too call them, but are somehow related to the `Class/Type`

```
1  #include <iostream>
2  using std::cout;
3  using std::endl;
4
5  int main() {
6    Point p1(2, 2);
7    Point p2(1, 1);
8    // Call the static method of the class Point
9    cout << "Dist is " << Point::Dist(p1, p2) << endl;
10
11   // Call the class-method of the Point object p1
12   cout << "Dist is " << p1.Dist(p2) << endl;
13 }
```

Using for type aliasing

- Use word `using` to declare new types from existing and to create type aliases
- **Basic syntax:** `using NewType = OldType;`
- `using` is a versatile word
- When used outside of functions declares a new type alias
- When used in function creates an alias of a type available in the current scope
- http://en.cppreference.com/w/cpp/language/type_alias

Using for type aliasing

```
1  #include <array>
2  #include <memory>
3  template <class T, int SIZE>
4  struct Image {
5    // Can be used in classes.
6    using Ptr = std::unique_ptr<Image<T, SIZE>>;
7    std::array<T, SIZE> data;
8  };
9  // Can be combined with "template".
10 template <int SIZE>
11 using Imagef = Image<float, SIZE>;
12 int main() {
13   // Can be used in a function for type aliasing.
14   using Image3f = Imagef<3>;
15   auto image_ptr = Image3f::Ptr(new Image3f);
16   return 0;
17 }
```

Enumeration classes

- Store an enumeration of options
- Usually derived from `int` type
- Options are assigned consequent numbers
- Mostly used to pick path in `switch`

```
1 enum class EnumType { OPTION_1, OPTION_2, OPTION_3 };
```

- Use values as:
  `EnumType::OPTION_1`, `EnumType::OPTION_2`, ...
- GOOGLE-STYLE Name enum type as other types, `CamelCase`
- GOOGLE-STYLE Name values as constants `kSomeConstant` or in `ALL_CAPS`

```cpp
#include <iostream>
#include <string>
using namespace std;
enum class Channel { STDOUT, STDERR };
void Print(Channel print_style, const string& msg) {
  switch (print_style) {
    case Channel::STDOUT:
      cout << msg << endl;
      break;
    case Channel::STDERR:
      cerr << msg << endl;
      break;
    default:
      cerr << "Skipping\n";
  }
}
int main() {
  Print(Channel::STDOUT, "hello");
  Print(Channel::STDERR, "world");
  return 0;
}
```

Explicit values

- By default enum values start from `0`
- We can specify custom values if needed
- Usually used with default values

```
1 enum class EnumType {
2   OPTION_1 = 10,    // Decimal.
3   OPTION_2 = 0x2,   // Hexacedimal.
4   OPTION_3 = 13
5 };
```

Characteristic of OOP

1. Object
2. Abstraction
3. Inheritance
4. Encapsulation
5. Polymorphism

--- more ---

aggregation

composition

relation among class & object

--- parent & child

Object → data ගොනුව ඇතුළත් කරයි

→ data member (data) properties / state

→ data mem function / method / action

Class → Class properties →

Objectවල ගුණාංග

Object properties ⇒ Class properties

Abstraction

- တည်ဆောက်မှုပြု / ပြင်ဆင်လို့မရတဲ့ class → Abstract class

ပုံ၊ ဥပမာ

```
Phone {
    call();
    sms();
}

Phone Samsung;

Phone Iphone;
```

- ပိုင်ဆိုင်တဲ့ variable ရဲ့ methods တွေကိုပဲ ထားပါတယ်.

Inheritance

- OOP ရဲ့ အရေးကြီး Role, ကဏ္ဍတစ်ခု

```
Class Android : Phone
{
    // do something
};
```

- base class (parent class) ထဲက properties ရဲ့ function တွေကို child class မှာပြန်သုံးလို့ရတယ်
- ဒီက class ရဲ့ ဒါလိုမျိုးရှင်းလင်းတွေကို ၊ code reuse

access specifiers

(14) inheritance, multi level inherit, Multiple inheritance,

Encapsulation

- ဖုံးကွယ်ခြင်း ၊ တချို့ကိစ္စတွေ ဖုံးကွယ်ထားမယ် ၊ complex code ကိုပဲ ဖော်ပြ မသိစေချင်
- C++ မှာ ကိုယ်ပိုင် modifier ဆိုတာ visibility ၃ မျိုး ရှိ
- C#, Java တို့မှာ ၅ မျိုး / ၆ မျိုး ထောက်ပံ့ပေးတယ်

C++

Public

ပြုလုပ်ထား properties တွေသည် child class, တွေ object တွေက ပါ အသုံးပြုနိုင်ပါတယ်

Private

ပြုလုပ်ထား data တွေကတော့ မူရင်း class ထဲကသာ အသုံးပြုနိုင်ပါတယ်။ child class တွေ, object တွေက မသုံးနိုင်ပါ။

Protected

ပြုလုပ်ထား ကောင်တွေ ကတော့ inheritance နဲ့ ရယူ သုံးနိုင်ပါတယ်၊ ဆိုလိုတာက child class တွေက ရယူ သုံးစွဲနိုင် ပါတယ်၊ object တွေ ကတော့ အသုံးမပြုနိုင်ပါဘူး။

Assembly {
ns { class
class }
ns { class
class }
}

C#
public
private
protected
Internal
Protected Internal

C#, Java မှာဆို ပါဝင်တဲ့ language တွေမှာတော့ internal ဆိုတာကိုလည်းတော့ public နဲ့ တူ အသုံးပြုနိုင်ပါတယ်၊ Namespace ကနေ ခေါ်လို့တော့ မရတော့ပါဘူး။

Polymorphism ← function

Interface တစ်ခုတည်း ကိုအများကြီး ပုံစံပြောင်းတဲ့ Object ပုံ ပုံစံအမျိုးမျိုး ဖြစ်တာကို Polymorphism လို့ခေါ်တယ်

Function Name တူပေမဲ့ Object ပေါ်မူတည်ပြီး ပုံစံပြောင်းသွားတယ် ဥပမာ Circle Area(), Square Area() တို့

Polymorphism ၂မျိုး
- → Compile time polymorphism
  - → Function Overloading
  - → Operator Overloading
- → Runtime Polymorphism

Class function ရဲ့ function definition ကို compile time မှာ binding လုပ်တယ်

Class function ရဲ့ definition ကို Runtime မှာ binding လုပ်တယ်

Base Virtual fun() ဆိုတာ initialize မလုပ်ဘဲ define မလုပ်ထားရင် =0;

အခြေခံအားဖြင့် Base Class က virtual method

Abstract method ဖြစ်ပြီး ...

Child ကနေ parent ရဲ့ method ကို override လုပ်တာ

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