Code Organization and Templates

Preprocessors, Header and Source Files, Templated Code

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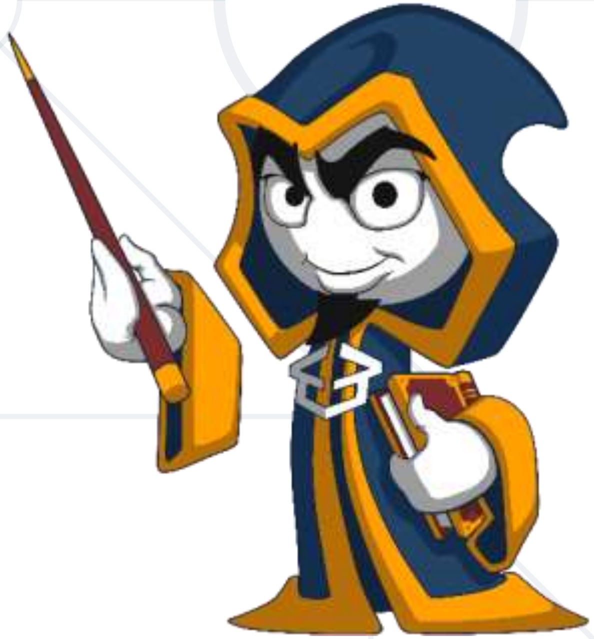

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Preprocessor Directives

#include, #define, #if…

Preprocessor Directives

- Executed before compilation
- Instruct compiler how and what to compile
  - Not part of the code, they modify the code
  - `#include` – adds code to the compilation unit
  - `#define` – essentially a find-and-replace in the code
  - `#if`, `#ifdef`, `#else`... – use / skip code based on an expression
  - `#pragma` – compiler-specific settings

#include and #define

- **`#include <X>`** copies system **X** source in this file
  - **`#include "X"`** first looks for local file **X** , then for system **X**

```
#include <iostream>      // directly looks for system file iostream
#include "01. Macros.h" // looks for local file "01. Macros.h"
```

- **`#define X Y`** – macro, replaces **X** in the code with **Y**

```
#define PI 3.14
cout << PI << endl; // prints 3.14
```

- **`#define F(X) code-using-X`** – macro function

```
#define SHOW(something) cout << something << endl;
SHOW("hello macros"); // prints "hello macros"
```

Conditional Inclusions and Header Guards

- Similar to if-else, when condition is NOT met, code is ignored
  - **#if** and **#elif** – "else if "
  - **#else** - "closed" with **#endif**
  - **#ifdef X** – if macro **X** is defined
  - **#ifndef** – if macro **X** is NOT defined

```
#ifdef _WIN32
system("cls");
#else
system("clear");
#endif
```

- **Header guards** – avoid **#include**-ing code multiple times

```
#ifndef SOME_FILE_H // use any macro name unique for the file
#define SOME_FILE_H
// code here safe from multi-inclusion
#endif // !SOME_FILE_H
```

Separating Declaration and Implementation

Separating Declaration and Implementation

- Allows separate **declaration** and **implementation**
- For **functions**, **methods**, **operators**, **classes**
- Class members' implementation is **often separated**
  - Cleaner **view of class** "interface"
  - Sometimes **necessary** (static fields or stream operators)
  - Code needed for the implementation is **not included in the header**
  - Allows separate build objects for **faster** rebuilds and **dynamic** linking

Why Separate?

```
class Company {    // PART ONE
private:
int id;
string name;
vector<std::pair<char, char> > employees;

public:
Company(int id, string name, vector<pair<char, char> > employees)
: id(id), name(name), employees(employees) {}

int getId() const {
  return this->id;
}

string getName() const {
  return this->name;
} // more on the next slide ->
```

Why Separate?

```
vector<pair<char, char> > getEmployees() const {    // PART TWO
  return this->employees;
}

string toString() {
  ostringstream stream;
  stream << id << " " << name << " ";

  for (int i = 0; i < employees.size(); i++) {
    auto initials = employees[i];
    stream << initials.first << initials.second;
    if (i < employees.size() - 1) {
      stream << " ";
    }
  }
  return stream.str();
} // more on the next slide ->
```

Why Separate?

```
bool operator==(const Company& other) const {    // PART THREE
  return this->id == other.id;
}

string operator+(const string& s) {
  return this->toString() + s;
}

Company& operator+=(const pair<char, char>& employee) {
  this->employees.push_back(employee);

  return *this;
}

};  // end
```

Separating Declarations and Implementation

```
class Company {
private:
    int id;
    string name;
    vector<pair<char, char> > employees;

public:
    Company(int id, string name, vector<pair<char, char> > employees);

    int getId() const;
    string getName() const;
    vector<pair<char, char> > getEmployees() const;
    string toString() const;
    bool operator==(const Company& other) const;
    std::string operator+(const char* s) const;
    std::string operator+(const string& s);

    Company& operator+=(const pair<char, char>& employee);
};
```

Separating Member Definitions

- Syntax same as a member inside a class, however:
  - Prefixed with namespaces and class name, joined by **operator::**

```
Company::Company(int id, string name, vector<pair<char, char> > employees)
: id(id), name(name), employees(employees) {}
...
int Company::getId() const {
  return this->id;
}
...
bool Company::operator==(const Company& other) const {
  return this->id == other.id;
}
...
```

Header and Source Files

Header and Source Files

- **Header files** – mostly declarations
  - Use **`#pragma once`** to avoid multi-inclusion
  - Extension – **`.h`**/**`.hpp`**/**`.h++`**
- **Source files** – implements header declarations
  - Usually **1** per header, **`#include`** the header
  - Extension – **`.cpp`**

Header Files - Company.h

```
#pragma once

#include <string>
#include <vector>
class Company {
    private:
      int id; string name;
      vector<pair<char, char> > employees;
    public:
    Company(int id, string name,
      vector<pair<char, char> > employees);
    ...
    int getId() const;
    ...
    bool operator==(const Company& other) const;
};
```

Source Files - Company.cpp

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```cpp
#include "Company.h"

Company::Company(int id, string name,
  vector<pair<char, char> > employees)
  : id(id), name(name), employees(employees) {}
...
int Company::getId() const {
  return this->id;
}
...
bool Company::operator==(
    const Company& other) const {
  return this->id == other.id;
}
...
```

Build

Building Multiple Sources

- **Compilation unit** – a file (usually `.cpp`) the compiler works on
- Build process for each unit:
  - `.cpp` -> expanded source (insert **`#include`** code, macros, etc.)
  - expanded source -> platform code -> assembly code
  - assembly code -> object code, **`.o`**/**`.obj`** (**`1`**'s & **`0`**'s)
- Linking: object code files -> **linked** -> final executable

Building Multiple Sources

- Different approaches to building a multi-source "Project"
  - Single `.cpp`, implementation in headers – compile the `.cpp`
  - Only declaration in `.h`, multiple `.cpp` – compile and link all `.cpp`
  - Mixed – some `.h` contain implementation – same as above
- Compiler needs instructions on which files to compile
  - IDEs automate the process – compile and link all `.cpp` files

Templates

Generalizing Functions and Classes for any Type

Algorithm vs. Data Type

- Algorithms rarely operate on a single data type
- E.g. calculate what percentage **a** is of **b**
  - a out of **b** == `a * 100 / b`
  - 1 out of **4** == `1 * 100 / 4` == `25%`
  - `1.5` out of `3` == `1.5 * 100 / 3` == `50%`
  - ¼ out of ½ == `¼ * 100 / ½` == `25 / ½` == `50%`

Templates

- What should **`T`** be here: **`T calcPercentage(T a, T b)`**?
  - **`int`**, **`double`** or **`Fraction`**? All of them can be **`T`**
  - **`T`** here only needs **`operator*`** and **`operator/`**
- **Templates**
  - Declare function or class with a "**placeholder**" type
  - Can use with **different types**
  - Types should support the **used methods / operators**

Function Templates

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- **template<typename T>** – makes **T** a placeholder type
  - Can have multiple placeholders

```
template<typename T>
T calcPercentage(const T& a, const T& b)
{
  return (a * 100) / b;
}
```

  - Applies only to function/class directly after it

```
template<class KeyType, class ValueType>
void printPair(const KeyType& a, const ValueType& b)
{
  cout << [ << a << ] << "->" << b << endl;
}
```

  - **template<class T>** has same meaning

Calling Templated Functions

- Call like normal function

```
calcPercentage(5, 10) // compiles & executes for int
```

- If type doesn't support operations in function

```
calcPercentage(5, " ")
// compilation error in calcPercentage for operator* and operator/
```

- May need **<Type>** after name to specify type
  - E.g. `calcPercentage<double>(0.5, 1)`

Class Templates

- Classes can receive templates to use as data types
  - **vector<T>**, **list<T>**, **map<K, V>**
- Defining class template – same as with function

```
template<typename T> class ClassName { ... }
```

  - Can use **T** for fields, methods, etc. – like any actual type
- Using a class template

```
ClassName<int> a;
ClassName<Fraction> b;
```

Class Templates – Example

- Making a **`Pair`** class similar to **`std::pair`**
  - Use the same way

```
Pair<string, int> ben{
  "Ben Dover", 42
};

cout << ben.first << " "
  << ben.second;
```

```
#ifndef PAIR_H
#define PAIR_H
template<class T1, class T2>
class Pair {
public:
  T1 first; T2 second;
  Pair(T1 first, T2 second)
    : first(first)
    , second(second) {
  }
};
#endif // !PAIR_H
```

Access Template Subtype – typename

- **`operator::`** to access class inside **T**, prefix with **`typename`**

```
typename T::SubClassName subClassObject;
```

- Can also use **`class`** instead of **`typename`**

```
template<typename Container> void print(Container container)
{
  typename Container::iterator i;
  for (i = container.begin(); i != container.end(); i++)
  {
    std::cout << *i << " ";
  }
  std::cout << std::endl;
}
```

Template Specialization

- Can define different behavior for specific template value

```
template<typename T> void print(T container)
{
  typename T::iterator i;
  ...
}
template<> void print<string>(string container)
{
  cout << container << endl;
}
```

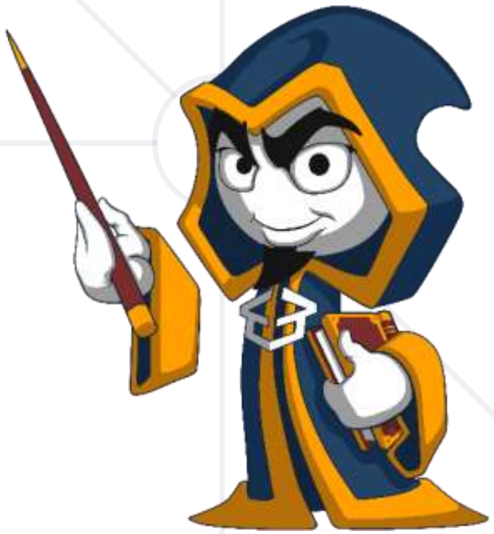
```
vector<int> numbers{ 1, 2, 3 }; string s = "hello specialization";
print(numbers); // prints "1 2 3 "
print(s); // prints "hello specialization"
```

Template Specifics

- Template declaration and definition **must be in the same file**
  - Can not separate class template in `.h` and `.cpp` files
- Template parameters **can be constant values**
  - `template<int N>` - use N as a constant in function/class
- Templates are **not instantiated in code until used**
  - When used, compiler copies template with the type
- Template **metaprogramming**
  - Uses templates to generate results compile-time

Summary

- Preprocessor directives
  - Execute before compilation and edit code
  - Macros, Inclusions & Header-guards
- Code is often split into header and source files
  - `.h` contains declarations, `.cpp` contains definition
  - IDEs usually compile & link all `.cpp` files
- Templates allow using the same code for different types
  - Functions and classes can be templates



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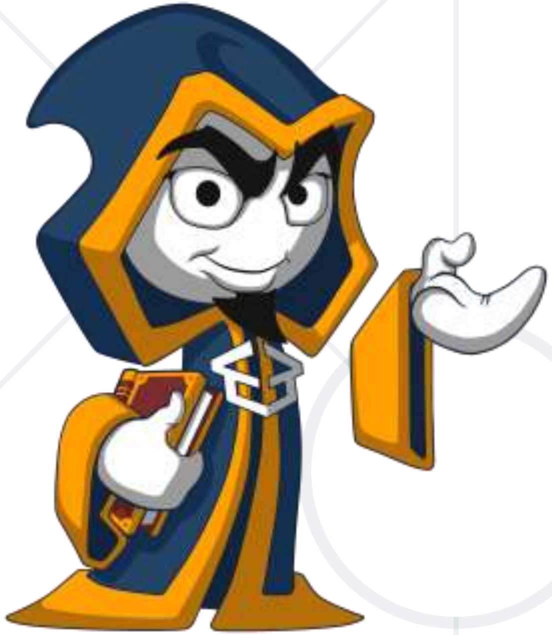

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