TDDE18 & 726G77

Templates

Duplicate code – functions

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

int main() {
	cout << sum(1, 2) << endl;
}
```

Duplicate code – functions

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

int main() {
	cout << sum(1, 2) << endl;
	cout << sum(1.0, 2.5) << endl;    // Compiler warning and wrong result
}
```

Duplicate code – functions

```
int sum(int a, int b) {
	return a + b;
}
double sum(double a, double b) {
	return a + b;
}

int main() {
	cout << sum(1, 2) << endl;
	cout << sum(1.0, 2.5) << endl;
}
```

Duplicate code – functions

```
int sum(int a, int b) {
	return a + b;
}
double sum(double a, double b) {
	return a + b;
}

int main() {
	cout << sum(1, 2) << endl;
	cout << sum(1.0, 2.5) << endl;
	cout << sum(“a”, “b”) << endl; // Does not compiles
}
```

Duplicate code – functions

```
int sum(int a, int b) {
        return a + b;
}
double sum(double a, double b) {
        return a + b;
}
string sum(string a, string b) {
        return a + b;
}

int main() {
        cout << sum(1, 2) << endl;
        cout << sum(1.0, 2.5) << endl;
        cout << sum(“a”, “b”) << endl;
}
```

Function templates

- A function template defines a family of functions
- Function templates are special functions that can operate with *generic types.*
- Create a function template whose functionality can be adapted to more than one type or class without repeating the entire code for each type.
- This is achieved by using *template parameters*, which is a special kind of parameter that can be used to pass a type argument: just like regular function parameters can be used to pass values to a function.

Template parameters

- The format for declaring function templates with type parameters is:

```
template <class identifier> function_declaration;
template <typename identifier> function_declaration;
```

- The only difference between both prototypes is the use of either the keyword class or the keyword typename. The use is indistinct, they have the exact same meaning and behave exactly the same way.

Function templates – example

```
template <typename T>
T sum(T a, T b) {
	return a + b;
}

int main() {
	cout << sum(1, 2) << endl;	// invoking sum(int, int);
	cout << sum(1.0, 2.5) << endl;	// invoking sum(double, double);
}
```

Function templates – example

```
template <typename T>
T sum(T a, T b) {
	return a + b;
}

int main() {
	cout << sum(1, 2) << endl;		// invoking sum(int, int);
	cout << sum(1.0, 2.5) << endl;		// invoking sum(double, double);
	cout << sum<double>(1, 2) << endl; // invoking sum(double, double);
}
```

Function templates – example

```
template <typename T>
T sum(T a, T b) {
        return a + b;
}

int main() {
        cout << sum(1, 2) << endl;          // invoking sum(int, int);
        cout << sum(1.0, 2.5) << endl;      // invoking sum(double, double);
        cout << sum<double>(1, 2) << endl; // invoking sum(double, double);
        cout << sum('1', '2') << endl;      // invoking sum(char, char);
}
```

Function templates – example

```
template <typename T>
T sum(T a, T b) {
        return a + b;
}

int main() {
        cout << sum(‘1’, ‘2’) << endl;  // invoking sum(char, char);
                                        // will return ‘c’ due to ascii table
                                        // value, but what if we want “12”
                                        // instead?
}
```

Function templates and overload resolution

- Function templates can be overloaded with both template functions and normal functions.
- Overload resolution basically goes through the following steps to find a function to match a call:
  - if there is a normal function that exactly matches the call, the function is selected, else
  - if a function template can be instantiated to exactly match the call, that specialization is selected, else
  - if type conversion can be applied to the arguments, allowing a normal function to be used as a unique best match, that function is selected, else
  - overload resolution fails

Function templates – example

```
template <typename T>
T sum(T a, T b) {
        return a + b;
}

string sum(char a, char b) {
        return string(1, a) + string(1, b);
}

int main() {
        cout << sum(‘1’, ‘2’) << endl;  // invoking sum(char, char);
                                        // returns “12”
}
```

Function templates and overload resolution

```
template <typename T>
T const& max(T const& x, T const& y);


int a, b;
double x, y;


max(a, b);              // Ok, a and b have same type, int
max(x, y);              // Ok, x and y have same type, double
max(a, x);              // ERROR, a and x has different type
max<double>(a, x);      // explicit instantiation allows for implicit type
                        // conversation, a is converted to double
```

Duplicate code – class

```
class Value_Int {
        int value;
...
};

class Value_Double {
        double value;
...
};

class Value_Char {
        char value;
...
};
```

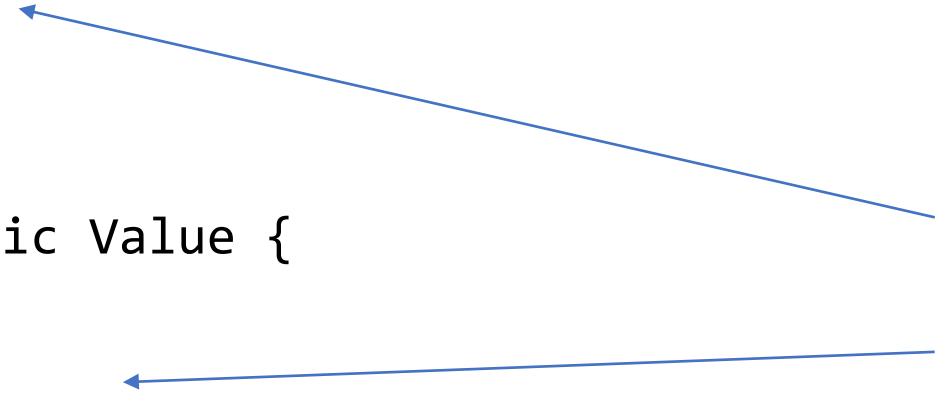
Class hierarchy solution (1)

```
class Value {
};

class Value_Int : public Value {
     int value;
};

class Value_Double : public Value {
     double value;
};
```

Class hierarchy solution (2)

- Class hierarchy solves the problem of separating different behavior into different subclasses. As you can see the difference between sub classes are data members. The classes have the same behavior.

```
class Value_Int : public Value {
	int value;
	int getValue();
};

class Value_Double : public Value {
	double value;
	double getValue();
};
```



Different data types

Class templates

```
template <typename T>
class Value {
        T value;
        T getValue();
};
```

Class template instantiation and specialization

- implicit instantiation occurs when the context requires an instance of a class template
  - class template arguments are never deduced

    ```
    vector v; // error: missing template arguments before ‘v’
    ```
  - class template member functions are instantiated when called

    ```
    v.push_back(x);
    ```

Keyword: typename

- In a template declaration, ***typename*** can be used as an alternative to class to declare ***type template parameters***

  template <typename T>

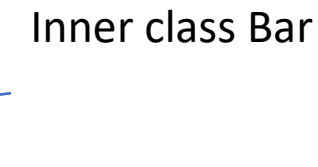
- Inside a declaration or a definition of a template, ***typename*** can be used to declare that a ***dependent name*** is a type

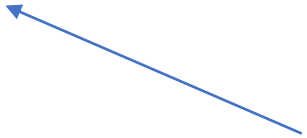
Declaration/definition of a template

- A name that is not a member of the current instantiation and is dependent on a template parameter is not considered to be a type unless the keyword typename is used

Declaration/definition of a template

```
template <typename T>
class Foo {
     class Bar {};
     Bar f();
};
```





How to declare function f() in cc-file?

Declaration/definition of a template

```
Foo::Bar f() {
        return Bar{};
}

// error: invalid use of template-name ‘Foo’ without and argument list
```

Declaration/definition of a template

```
template <typename T>
Foo<T>::Bar f() {
        return Bar{};
}


// error: need ‘typename’ before ‘Foo<T>::Bar’ because ‘Foo<T>’ is a dependent
scope
```

Declaration/definition of a template

```
template <typename T>
typename Foo<T>::Bar f() {
        return Bar{};
}

// compiles and works
```

Templates – file naming convention

- Header file – where the declarations need to be. Convention is to have the extension .h
- Implementation file – where the implementation needs to be. Convention is to have the extension .tpp

Example:

List.h

List.tpp

Template instantiating

- The compiler needs to have access to the implementation of the methods, to instantiate them with template arguments.
- If these implementations were not in the header, they wouldn't be accessible, and therefore the compiler wouldn't be able to instantiate the template.
- No need to compile the implementation file!

```
// header-file
#ifndef _LIST_H_
#define _LIST_H_
...

#include “List.tpp”
#endif
```

```
// implementation file
// no need to include the h-file
template<typename T>
typename List<T>::List() {
        ...
}
```

Exam information

- Jan 14th 2018 2pm – 7pm (5 hours)
- Be there early around 1.45pm to log in and prepare.
- 1 C++ book is allowed
- 1 A4-page (front and back) with your own notes
- 1 dictionary
- en.cppreference.com – only STL part is available

Exam information

- 5 assignments

Time	Solved assignments	Grade
$17.00 + B$	3	5
$18.00 + B$	4	5
$18.00 + B$	3	4
$16.00 + B$	2	4
19.00	2	3

Exam information

- 1 general problem solving
- 1 class hierarchy
- 1 file and containers
- 1 algorithms
- 1 misc.

Note: All assignments require some kind of problem solving skill!