

601.220 Intermediate Programming

Template classes

Template classes

When we learned STL, we considered these templates:

```
template< typename T >
struct Node {
    T payload;
    Node *next;
};

template< typename T >
void print_list(Node<T> *head) {
    Node<T> *cur = head;
    while(cur != NULL) {
        std::cout << cur->payload << " ";
        cur = cur->next;
    }
    std::cout << std::endl;
}
```

One `struct`/function that works for (almost) any type T

Template classes

```
// template1.cpp
```

```
1  #include "node_template.h"
2
3  int main() {
4      Node<float> f3 = {95.1f, NULL}; // float payload
5      Node<float> f2 = {48.7f, &f3};  // float payload
6      Node<float> f1 = {24.3f, &f2};  // float payload
7      print_list(&f1);
8
9      Node<int> i2 = {239, NULL};      // int payload
10     Node<int> i1 = {114, &i2};       // int payload
11     print_list(&i1);
12     return 0;
13 }
```

```
$ g++ -o template1 template1.cpp -std=c++11 -pedantic -Wall -Wextra
```

```
$ ./template1
```

```
24.3 48.7 95.1
```

```
114 239
```

Now we make it **a template class**.

Template classes

```
// template_class1.h

1  #include <iostream>
2
3  template< typename T >
4  class Node {
5  public:
6      Node(T pay, Node<T> *nx) : payload(pay), next(nx) { }
7
8      void print() const {
9          const Node<T> *cur = this;
10         while(cur != NULL) {
11             std::cout << cur->payload << ' ';
12             cur = cur->next;
13         }
14         std::cout << std::endl;
15     }
16
17 private:
18     T payload;
19     Node<T> *next;
20 };
```

Template classes

```
// template_class1.cpp
```

```
1  #include "template_class1.h"
2
3  int main() {
4      Node<float> f3 = {95.1f, NULL};
5      Node<float> f2 = {48.7f, &f3};
6      Node<float> f1 = {24.3f, &f2};
7      f1.print();
8
9      Node<int> i2 = {239, NULL};
10     Node<int> i1 = {114, &i2};
11     i1.print();
12     return 0;
13 }
```

```
$ g++ -o template_class1 template_class1.cpp -std=c++11 -pedantic -Wall -Wextra
```

```
$ ./template_class1
```

```
24.3 48.7 95.1
```

```
114 239
```

Template classes

Everything looks fine. Now lets separate the template class into a .h file and a .cpp file.

```
// template_class2.h
```

```
1  #ifndef NODE_TEMPLATE_H__
2  #define NODE_TEMPLATE_H__
3  template< typename T >
4  class Node {
5  public:
6      Node(T pay, Node<T> *nx) : payload(pay), next(nx) {}
7      void print() const;
8  private:
9      T payload;
10     Node<T> *next;
11 };
12 #endif // NODE_TEMPLATE_H__
```

Template classes

```
// template_class2.cpp

1  #include "template_class2.h"
2  #include <iostream>
3
4  template< typename T >
5  void Node<T>::print() const {
6      const Node<T> *cur = this;
7      while(cur != NULL) {
8          std::cout << cur->payload << ' ';
9          cur = cur->next;
10     }
11     std::cout << std::endl;
12 }
```

Template classes

```
// template_main2.cpp
```

```
1  #include "template_class2.h"
2  #include <iostream>
3
4  int main() {
5      Node<float> f3 = {95.1f, NULL};
6      Node<float> f2 = {48.7f, &f3};
7      Node<float> f1 = {24.3f, &f2};
8      f1.print();
9
10     Node<int> i2 = {239, NULL};
11     Node<int> i1 = {114, &i2};
12     i1.print();
13     return 0;
14 }
```

```
$ g++ -o template_main2 template_main2.cpp template_class2.cpp -std=c++11 -peda
```

```
/tmp/ccq8dbjt.o: In function 'main':
```

```
template_main2.cpp:(.text+0x6e): undefined reference to 'Node<float>::print() c
```

```
template_main2.cpp:(.text+0xa5): undefined reference to 'Node<int>::print() con
```

```
collect2: error: ld returned 1 exit status
```


Template instantiation

Compiler acts **lazily** when instantiating templates

It doesn't instantiate until **first use**

```
Node<float> f3 = {95.1f, NULL}; // OK fine, I'll instantiate Node<float>
Node<float> f2 = {48.7f, &f3};
Node<float> f1 = {24.3f, &f2};
f1.print(); // OK fine, I'll instantiate Node<float>::print

Node<int> i2 = {239, NULL}; // OK fine, I'll instantiate Node<int>
Node<int> i1 = {114, &i2};
i1.print(); // OK fine, I'll instantiate Node<int>::print
```

When instantiating, compiler **needs the relevant template classes and functions to be fully defined already** ...

... **in contrast to typical function or class use**, where definition can be in separate .cpp files. i.e. **template classes have to be typically defined in the header files.**

Template instantiation

```
$ g++ -o template_main2 template_main2.cpp template_class2.cpp -std=c++11 -peda
/tmp/ccpTOCNL.o: In function 'main':
template_main2.cpp:(.text+0x6e): undefined reference to 'Node<float>::print() c
template_main2.cpp:(.text+0xa5): undefined reference to 'Node<int>::print() con
collect2: error: ld returned 1 exit status
```

Lazily instantating Node<float> & Node<int> is fine

- Both are defined in the header

Instantating Node<float>::print() & Node<int>::print()
won't work

- They are in a separate source file not #included
- By convention, we never #include .cpp files

Template instantiation

There are a couple of possible solutions:

- Move `Node<T>::print()` definition back into the header
- Put member function definitions in a separate file and include it, but **don't** give it a `.cpp` extension. i.e. a different extension such as `.inc` or `.inl`.

```
// template_class2.inc
```

```
1  #include <iostream>
2
3  template< typename T >
4  void Node<T>::print() const {
5      const Node<T> *cur = this;
6      while(cur != NULL) {
7          std::cout << cur->payload << ' ';
8          cur = cur->next;
9      }
10     std::cout << std::endl;
11 }
```

Template instantiation

```
// template_main2_fixed.cpp
```

```
1  #include "template_class2.h"    // template class definition
2  #include "template_class2.inc"  // template class member function definitions
3
4  int main() {
5      Node<float> f3 = {95.1f, NULL}; // instantiate Node<float>
6      Node<float> f2 = {48.7f, &f3};
7      Node<float> f1 = {24.3f, &f2};
8      f1.print(); // instantiate Node<float>::print    *** will this work? ***
9
10     Node<int> i2 = {239, NULL};    // instantiate Node<float>
11     Node<int> i1 = {114, &i2};
12     i1.print(); // instantiate Node<int>::print      *** will this work? ***
13     return 0;
14 }
```

```
$ g++ -o template_main2_fixed template_main2_fixed.cpp -std=c++11 -pedantic -Wa
```

```
$ ./template_main2_fixed
```

```
24.3 48.7 95.1
```

```
114 239
```