

Function Templates

- Many functions have the same code body regardless of type.

for (i = 0; i < n; i++) a[i] = b[i];

Function Templates (2)

- Most C programmers automate this with a simple **macro**.

```
#define COPY (A, B, N) {      \|  
int i;                        \|  
for (i = 0; i < N; i++)      \|  
    A[i] = B[i];              \|  
}
```

Function Templates (3)

1. This works but **not** "type-safe". A user could **mix** types when conversions were inappropriate.
2. Macros present the possibility for serious "side effects" and do not enable compiler to perform type checking.

Function Templates (4)

- Function template approach in C++.

```
template <class T>  
void copy(T a[], T b[], int n) {  
    for (int i = 0; i < n; i++) a[i] = b[i];  
}
```

Function Templates (5)

- Moreover, a generic copying procedure that accepts two distinct class type arguments.

```
template <class T1, class T2>  
void copy(T1 a[], T2 b[], int n) {  
    for (int i = 0; i < n; i++) a[i] = b[i];  
}
```

Function Templates (6)

- A function template itself may be **overloaded** as well.

Class Templates

- A class template lets you generate multiple versions of a class definition, providing an alternative to **derivation**.
- Derivation lets you **add** fields to an existing structure; templates let you change the **type** definition of an existing field within the structure.

Class Templates (2)

- Class templates are called **parameterized types** because they require one or more type parameters.
- Class template can contain **friends**. A friend function that does not use a template specification is universally a friend of all instantiations of the **class template** (each one is a **template class**).

Class Templates (3)

- A friend function that incorporates template arguments is specifically a friend of its instantiated class.

template <class T>

```
class foo {
```

```
friend void bar();    // universal
```

```
friend vect<T> product(vect<T> v);
```

```
// instantiated
```

}

Class Templates (4)

- Static members are **not** universal but are **specific** to each instantiation.

```
template <class T>  
class foo {  
    static int count;  
}
```

```
template <class T> int foo<T>::count = 0;
```

Class Templates (5)

foo <int> a;

foo <double> b;

- The static variables *foo<int>::count* and *foo<double>::count* are **distinct**.

Class Templates (6)

- Class templates can have **non-type** parameters, which can have default arguments and are treated as "***const***".

```
template <class T, int number> array .....  
array <int, 10> a;
```

C++ I/O

- Occurs in stream of **bytes**, where a stream is logical device that either produces or consumes information.
- When a C++ program begins, four streams are automatically opened: "***cin***", "***cout***", "***cerr***", and "***clog***".
- The output operator is **left** associative and returns a value of type "*ostream &*".

Manipulator

- A manipulator is a value or function that has a special effect on the stream it operates on. A simple example of a manipulator is "***endl***" whose effect is to output a newline and then flush the ostream.
- The manipulators "***dec***", "***hex***", and "***oct***" can be used to change integer **bases**.

Manipulator (2)

- "***setw***" is a manipulator that changes the default field width to the value of its argument.
- **Each time** an output operation is performed, the field width returns to its default setting, so it may be necessary to set the minimum field width before **each** output statement.

Manipulator (3)

- By default, six digits are displayed after the decimal point when floating-point values are output, you can set this number by using the "***setprecision***" manipulator.

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Chapter 12 - Templates

Outline

- 12.1 Introduction
- 12.2 Function Templates
- 12.3 Overloading Template Functions
- 12.4 Class Templates
- 12.5 Class Templates and Non-type Parameters
- 12.6 Templates and Inheritance
- 12.7 Templates and friends
- 12.8 Templates and static Members



12.1 Introduction

- Templates - easily create a large range of related functions or classes
 - function template - the blueprint of the related functions
 - template function - a specific function *made* from a function template



12.2 Function Templates

- overloaded functions
 - perform **similar** operations on different data types
- function templates
 - perform **identical** operations on different data types
 - provide type checking

- Format:

```
template<class type, class type...>
```

- can use **class** or **typename** - specifies type parameters

```
template< class T >
```

```
template< typename ElementType >
```

```
template< class BorderType, class FillType >
```

- Function definition follows **template** statement



12.2 Function Templates (II)

```
1  template< class T >
2  void printArray( const T *array, const int
count )
3  {
4      for ( int i = 0; i < count; i++ )
5          cout << array[ i ] << " ";
6
7      cout << endl;
8  }
```

T is the type parameter. **T**'s type is detected and substituted inside the function.

The newly created function is compiled.

The **int** version of **printArray** is

```
void printArray( const int *array, const int count )
{
    for ( int i = 0; i < count; i++ )
        cout << array[ i ] << " ";

    cout << endl;
}
```



12.3 Overloading Template Functions

- related template functions have same name
 - compiler uses overloading resolution to call the right one
- function template can be overloaded
 - other function templates can have same name but different number of parameters
 - non-template function can have same name but different arguments
- compiler tries to match function call with function name and arguments
 - if no precise match, looks for function templates
 - if found, compiler generates and uses template function
 - if no matches or multiple matches are found, compiler gives error



12.4 Class Templates

- class templates
 - allow type-specific versions of generic classes
- Format:

```
template <class T>
class ClassName{
    definition
}
```

- Need not use "**T**", any identifier will work
- To create an object of the class, type

```
ClassName< type > myObject;
```

```
Example: Stack< double > doubleStack;
```



12.4 Class Templates (II)

- Template class functions
 - declared normally, but preceded by **template<class T>**
 - generic data in class listed as type **T**
 - binary scope resolution operator used
 - Template class function definition:

```
template<class T>  
MyClass< T >::MyClass(int size)  
{  
    myArray = new T[size];  
}
```

- constructor definition - creates an array of type **T**





Outline



1. Class template definition

1.1 Function definitions

1.2 stack constructor

```
1 // Fig. 12.3: tstack1.h
2 // Class template Stack
3 #ifndef TSTACK1_H
4 #define TSTACK1_H
5
6 template< class T >
7 class Stack {
8 public:
9     Stack( int = 10 );    // default constructor (stack size 10)
10    ~Stack() { delete [] stackPtr; } // destructor
11    bool push( const T& ); // push an element onto the stack
12    bool pop( T& );        // pop an element off the stack
13 private:
14    int size;              // # of elements in the stack
15    int top;               // location of the top element
16    T *stackPtr;           // pointer to the stack
17
18    bool isEmpty() const { return top == -1; } // utility
19    bool isFull() const { return top == size - 1; } // functions
20 };
21
22 // Constructor with default size 10
23 template< class T > ←
24 Stack< T >::Stack( int s )
25 {
26     size = s > 0 ? s : 10;
27     top = -1;                // Stack is initially empty
28     stackPtr = new T[ size ]; // allocate space for elements
29 }
```

Notice how a member function of the class template is defined

12.5 Class Templates and Non-type Parameters

- can use non-type parameters in templates
 - default argument
 - treated as **const**
- Example:

```
template< class T, int elements >  
Stack< double, 100 >  
    mostRecentSalesFigures;
```

- declares object of type `Stack< double, 100>`

- This may appear in the class definition:

```
T stackHolder[ elements ]; //array to hold stack
```

- creates array at compile time, rather than dynamic allocation at execution time



12.6 Templates and Inheritance

- A class template can be derived from a template class
- A class template can be derived from a non-template class
- A template class can be derived from a class template
- A non-template class can be derived from a class template



12.7 Templates and friends

- friendships allowed between a class template and
 - global function
 - member function of another class
 - entire class
- **friend** functions
 - inside definition of class template **X**:
 - **friend void f1();**
 - **f1()** a **friend** of **all** template classes
 - **friend void f2(X< T > &);**
 - **f2(X< int > &)** is a **friend** of **X< int >** only. The same applies for **float**, **double**, etc.
 - **friend void A::f3();**
 - member function **f3** of class **A** is a **friend** of all template classes



12.7 Templates and friends (II)

- **friend void C< T >::f4(X< T > &);**
 - C<float>::f4(X< float> &) is a **friend** of class X<float> only

- **friend classes**

- **friend class Y;**
 - every member function of **Y** a friend with every template class made from **X**
- **friend class Z<T>;**
 - class **Z<float>** a **friend** of class **X<float>**, etc.



12.8 Templates and static Members

- non-template class
 - **static** data members shared between all objects
- template classes
 - each class (**int**, **float**, etc.) has its own copy of **static** data members
 - **static** variables initialized at file scope
 - each template class gets its own copy of **static** member functions



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Chapter 11- C++ Stream Input/Output

Outline

- 11.1 Introduction
- 11.2 Streams
 - 11.2.1 Iostream Library Header Files
 - 11.2.2 Stream Input/Output Classes and Objects
- 11.3 Stream Output
 - 11.3.1 Stream-Insertion Operator
 - 11.3.2 Cascading Stream-Insertion/Extraction Operators
 - 11.3.3 Output of char * Variables
 - 11.3.4 Character Output with Member Function put; Cascading puts
- 11.4 Stream Input
 - 11.4.1 Stream-Extraction Operator
 - 11.4.2 get and getline Member Functions
 - 11.4.3 istream Member Functions peek, putback and ignore
 - 11.4.4 Type-Safe I/O
- 11.5 Unformatted I/O with read, gcount and write
- 11.6 Stream Manipulators
 - 11.6.1 Integral Stream Base: dec, oct, hex and setbase
 - 11.6.2 Floating-Point Precision (precision, setprecision)
 - 11.6.3 Field Width (setw, width)
 - 11.6.4 User-Defined Manipulators
- 11.7 Stream Format States
 - 11.7.1 Format State Flags
 - 11.7.2 Trailing Zeros and Decimal Points (ios::showpoint)
 - 11.7.3 Justification (ios::left, ios::right, ios::internal)
 - 11.7.4 Padding (fill, setfill)
 - 11.7.5 Integral Stream Base (ios::dec, ios::oct, ios::hex, ios::showbase)
 - 11.7.6 Floating-Point Numbers; Scientific Notation (ios::scientific, ios::fixed)
 - 11.7.7 Uppercase/Lowercase Control (ios::uppercase)
 - 11.7.8 Setting and Resetting the Format Flags (flags, setiosflags, resetiosflags)
- 11.8 Stream Error States
- 11.9 Tying an Output Stream to an Input Stream



11.1 Introduction

- Many C++ I/O features are object-oriented
 - use references, function overloading and operator overloading
- Extensibility
 - Users may specify I/O of user-defined types as well as standard types



11.2 Streams

- Stream
 - A transfer of information in the form of a sequence of bytes
- I/O Operations:
 - Input: A stream that flows from an input device (i.e.: keyboard, disk drive, network connection) to main memory
 - Output: A stream that flows from main memory to an output device (i.e.: screen, printer, disk drive, network connection)



11.2 Streams (II)

- I/O operations are a **bottleneck**
 - The time for a stream to flow is many times larger than the time it takes the CPU to process the data in the stream
- Low-level I/O
 - unformatted
 - individual byte unit of interest
 - high speed, high volume, but inconvenient for people
- High-level I/O
 - formatted
 - bytes grouped into meaningful units: integers, characters, etc.
 - good for all I/O except high-volume file processing



11.2.1 Iostream Library Header Files

- **iostream** library:
 - **<iostream.h>**: Contains **cin**, **cout**, **cerr**, and **clog** objects
 - **<iomanip.h>**: Contains *parameterized stream manipulators*
 - **<fstream.h>**: Contains information important to user-controlled file processing operations



11.2.2 Stream Input/Output Classes and Objects

- **ios:**
 - **istream** and **ostream** inherit from **ios**
 - **iostream** inherits from **istream** and **ostream**.
- **<<** (left-shift operator): overloaded as *stream insertion operator*
- **>>** (right-shift operator): overloaded as *stream extraction operator*
- Used with **cin**, **cout**, **cerr**, **clog**, and with user-defined stream objects



11.2.2 Stream Input/Output Classes and Objects (II)

- **istream:** input streams

cin >> someVariable;

- **cin** knows what type of data is to be assigned to **someVariable** (based on the type of **someVariable**).

- **ostream:** output streams

– **cout << someVariable;**

- **cout** knows the type of data to output

– **cerr << someString;**

- **Unbuffered**. Prints **someString** immediately.

– **clog << someString;**

- **Buffered**. Prints **someString** as soon as output buffer is full or flushed.



11.3.1 Stream-Insertion Operator

- `<<` is overloaded to output built-in types
 - can also be used to output user-defined types.
 - `cout << '\n';`
 - prints newline character
 - `cout << endl;`
 - `endl` is a stream manipulator that issues a newline character and flushes the output buffer
 - `cout << flush;`
 - `flush` flushes the output buffer.



11.3.2 Cascading Stream-Insertion/Extraction Operators

- `<<` : Associates from left to right, and returns a reference to its left-operand object (i.e. `cout`).
 - This enables cascading
`cout << "How" << " are" << " you?";`

Make sure to use [parenthesis](#):

```
cout << "1 + 2 = " << (1 + 2);
```

NOT

```
cout << "1 + 2 = " << 1 + 2;
```

How about
`cout << 1 < 2;`



11.3.4 Character Output with Member Function `put`; Cascading `puts`

- **`put`** member function
 - outputs one character to specified stream
`cout.put('A');`
 - returns a reference to the object that called it, so may be cascaded
`cout.put('A').put('\\n');`
 - may be called with an ASCII-valued expression
`cout.put(65);`
outputs **A**



11.4 Stream Input

- **>>** (stream-extraction)
 - used to perform stream input
 - Normally ignores whitespaces (spaces, tabs, newlines)
 - Returns zero (**false**) when **EOF** is encountered, otherwise returns reference to the object from which it was invoked (i.e. **cin**)
 - This enables cascaded input.
cin >> x >> y;
- **>>** controls the state bits of the stream
 - **failbit** set if wrong type of data input
 - **badbit** set if the operation fails



11.4.1 Stream-Extraction Operator

- `>>` and `<<` have relatively high precedence
 - conditional and arithmetic expressions must be contained in parentheses
- Popular way to perform loops

```
while (cin >> grade)
```

- extraction returns `0` (**false**) when **EOF** encountered, and loop ends





Outline



1. Initialize variables

2. Perform loop

3. Output

```
1 // Fig. 11.11: fig11_11.cpp
2 // Stream-extraction operator returning false on end-of-file.
3 #include <iostream>
4
5 using std::cout;
6 using std::cin;
7 using std::endl;
8
9 int main()
10 {
11     int grade, highestGrade = -1;
12
13     cout << "Enter grade (enter end-of-file to end): ";
14     while ( cin >> grade ) {
15         if ( grade > highestGrade )
16             highestGrade = grade;
17
18         cout << "Enter grade (enter end-of-file to end): ";
19     }
20
21     cout << "\n\nHighest grade is: " << highestGrade << endl;
22     return 0;
23 }
```

```
Enter grade (enter end-of-file to end): 67
Enter grade (enter end-of-file to end): 87
Enter grade (enter end-of-file to end): 73
Enter grade (enter end-of-file to end): 95
Enter grade (enter end-of-file to end): 34
Enter grade (enter end-of-file to end): 99
Enter grade (enter end-of-file to end): ^Z
Highest grade is: 99
```

Program Output

11.4.2 `get` and `getline` Member Functions

- `cin.get()`: inputs a character from stream (even white spaces) and returns it
- `cin.get(c)`: inputs a character from stream and stores it in `c`



11.4.2 `get` and `getline` Member Functions (II)

- **`cin.get(array, size):`**
 - accepts 3 arguments: array of characters, the size limit, and a delimiter (default of `'\n'`).
 - Uses the array as a buffer
 - When the delimiter is encountered, it remains in the input stream
 - Null character is inserted in the array
 - unless delimiter flushed from stream, it will stay there
- **`cin.getline(array, size)`**
 - operates like `cin.get(buffer, size)` but it discards the delimiter from the stream and does not store it in array
 - Null character inserted into array





Outline



1. Initialize variables

2. Input data

2.1 Function call

3. Output

```
1 // Fig. 11.12: fig11_12.cpp
2 // Using member functions get, put and eof.
3 #include <iostream>
4
5 using std::cout;
6 using std::cin;
7 using std::endl;
8
9 int main()
10 {
11     char c;
12
13     cout << "Before input, cin.eof() is " << cin.eof()
14         << "\nEnter a sentence followed by end-of-file:\n";
15
16     while ( ( c = cin.get() ) != EOF )
17         cout.put( c );
18
19     cout << "\nEOF in this system is: " <<
20     cout << "\nAfter input, cin.eof() is " << cin.eof() << endl;
21     return 0;
22 }
```

cin.eof() returns **false (0)** or **true (1)**

cin.get() returns the next character from input stream, including whitespace.

Before input, cin.eof() is 0
Enter a sentence followed by end-of-file:
Testing the get and put member functions^Z
Testing the get and put member functions
EOF in this system is: -1
After input cin.eof() is 1

Program Output

11.4.3 `istream` Member Functions `peek`, `putback` and `ignore`

- **`ignore`** member function
 - skips over a designated number of characters (default of one)
 - terminates upon encountering a designated delimiter (default is **EOF**, skips to the end of the file)
- **`putback`** member function
 - places the previous character obtained by **`get`** back in to the stream.
- **`peek`**
 - returns the next character from the stream without removing it



11.4.4 Type-Safe I/O

- << and >> operators
 - Overloaded to accept data of different types
 - When unexpected data encountered, error flags set
 - Program stays in control



11.6 Stream Manipulators

- stream manipulator capabilities:
 - setting field widths
 - setting precisions
 - setting and unsetting format flags
 - setting the fill character in fields
 - flushing streams
 - inserting a newline in the output stream and flushing the stream
 - inserting a null character in the output stream and skipping whitespace in the input stream.



11.6.1 Integral Stream Base: `dec`, `oct`, `hex` and `setbase`

- **`oct`, `hex`, or `dec`:**

- change base of which integers are interpreted from the stream.

Example:

```
int n = 15;  
cout << hex << n;
```

- prints "F"

- **`setbase`:**

- changes base of integer output
- load `<iomanip>`
- Accepts an integer argument (10, 8, or 16)

```
cout << setbase(16) << n;
```

- parameterized stream manipulator - takes an argument



11.6.2 Floating-Point Precision (`precision`, `setprecision`)

- **`precision`**

- member function
- sets number of digits to the right of decimal point
`cout.precision(2);`
- `cout.precision()` returns current precision setting

- **`setprecision`**

- parameterized stream manipulator
- Like all parameterized stream manipulators, `<iomanip>` required
- specify precision:

```
cout << setprecision(2) << x;
```

- For both methods, changes last until a different value is set



11.6.3 Field Width (`setw`, `width`)

- **`ios width`** member function
 - sets field width (number of character positions a value should be output or number of characters that should be input)
 - returns previous width
 - if values processed are smaller than width, fill characters inserted as padding
 - values are not truncated - full number printed
 - `cin.width(5);`
- **`setw`** stream manipulator
 - `cin >> setw(5) >> string;`
- Remember to reserve one space for the null character



11.7.2 Trailing Zeros and Decimal Points (`ios::showpoint`)

- **`ios::showpoint`**

- forces a float with an integer value to be printed with its decimal point and trailing zeros

```
cout.setf( ios::showpoint )
```

```
cout << 79;
```

79 will print as **79.00000**

- number of zeros determined by precision settings



11.7.3 Justification (`ios::left`, `ios::right`, `ios::internal`)

- **`ios::left`**
 - fields to left-justified with padding characters to the right
- **`ios::right`**
 - default setting
 - fields right-justified with padding characters to the left
- Character used for padding set by
 - **`fill`** member function
 - **`setfill`** parameterized stream manipulator
 - default character is space



11.7.4 Padding(fill, setfill)

- **fill** member function
 - specifies the fill character
 - space is default
 - returns the prior padding character

```
cout.fill( '*');
```

- **setfill** manipulator

- also sets fill character

```
cout << setfill ( '*');
```

