C++ PROGRAMMING WITH APPLICATIONS IN Administration, Finance and Statistics

This page is intentionally left blank

C++ PROGRAMMING WITH APPLICATIONS IN

Administration, Finance and Statistics

Willi-Hans Steeb & Fritz Solms
Rand Afrikaans University, Johannesburg, South Africa

Published by

World Scientific Publishing Co. Pte. Ltd.

P O Box 128, Farrer Road, Singapore 912805

USA office: Suite 1B, 1060 Main Street, River Edge, NJ 07661

UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

**C++ PROGRAMMING WITH APPLICATIONS IN
ADMINISTRATION, FINANCE AND STATISTICS**

Copyright © 2000 by World Scientific Publishing Co. Pte. Ltd.

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

ISBN 981-02-4066-X

This book is printed on acid and chlorine free paper.

Printed in Singapore by Fulsland Offset Printing

Preface

C++ is the most widely available and used object-oriented programming language. It is a very useful language that is successfully utilized by many programmers in many application areas. It is a reasonably carefully thought-out language where the design is based partly on acknowledged principles and partly on solid experience and feedback from actual use. The language is much more complicated and complex than, say, C and PASCAL. The key concepts of data abstraction and object-oriented programming are new to most people. One can use C++ effectively as a more strongly type checked C with a small amount of simple data abstraction and library use. This programming language has all the tools to write compact and comprehensive programs for finance, administration and statistics. Many of the most experienced individuals and organizations in the industry and academia use C++. Many programmers strongly prefer C++ over procedural languages such as C and PASCAL and deem the feature set provided by C++ as close to essential for their applications. C++ supports object-oriented programming. It supports it pretty well for real life applications. Its type system and general model of the world are coherent and relevant to real applications. C++ and its various implementations have a solid core where different compilers tend to agree and where the code generated is reliably good.

This book provides software solutions to problems in finance, administration and statistics. Most standard methods used in these fields are given together with their programs in C++. In some cases the output of the programs is also displayed. Moreover the book gives an introduction to C++. Most of the programs are written in C++. Some of the programs are written in C. All the standard methods such as number sorting, name sorting, applications of function templates, applications of class templates, inheritance, virtual classes, string manipulations are included.

In chapter 2 we give some basic programs in C++. These programs are very helpful for the beginners. They are also the building blocks for more complex applications. Chapter 3 is devoted to the manipulation of strings. The class concept is introduced in chapter 4. Chapter 5 and 6 deal with function and class templates. A collection of introductory programs are given. Sorting and searching algorithms are implemented in C++ in chapter 7. Chapter 8 gives a collection of useful classes. They include string classes, vector classes, a matrix class, linked lists, trees and a date class. Chapter 9 is devoted to output/input streams. Here we consider C and C++ programs. In chapter 10 a collection of applications in finance are given. Applications in administration are considered in chapter 11. Problems in statistics are considered in chapter 12. Chapter 13 describes exception handling. The standard template library is introduced in chapter 14 and several examples are given.

The level of presentation is such that one can study the subject early on in ones education in science. There is a balance between practical programming and the underlying language. The book is ideally suited for use in lectures on C, C++ and object-oriented programming. The beginner will also benefit from the book. Almost all C++ programs in the book comply to the ANSI C++ standard.

The reference list gives a collection of text books useful in the study of the computer language C++. There are a number of good text books for C++ available [3], [6], [7], [8], [11], [13], [9]. We also refer to *The Annotated C++ Reference Manual* by Margret Ellis and Bjarne Stroustrup [6]. For data structures we refer to Budd [4]. For applications in science we refer to Tan Kiat Shi and W.-H. Steeb [14] and Steeb [12]. The standard template library is described by Schildt [10], Ammeraal [1] and Budd [5].

For a comprehensive discussion of the Boyer-Moore algorithm, the Floyd-Warshall algorithm, Dijkstra algorithm, the sorting methods and the divide-and-conquer strategy we refer to Baase (1989) [2].

Without doubt, this book can be extended. If you have comments or suggestions, we would be pleased to have them. The email address of the first author is:

`whs@na.rau.ac.za`

The web page of the first author is:

`http://zeus.rau.ac.za/`

One of the authors (W.-H. Steeb) thanks his students from the Computational Science Programme of the National University of Singapore for stimulating discussions on object-oriented programming. They are: Fong Wei Leng, Heng Kok Liang, Tan Kiat Shi, Lee Wan Sie, Gan Chee Kwan, Toh Che Chou, Koh Mei Leng, Lee Yih, And Mieng Hwang, Teo Wee Chung, Lee Choon Meng.

Keywords in C++

C++ has the following keywords:

Table: C++ language keywords

asm	double	new	switch
auto	else	operator	template
break	enum	private	this
case	extern	protected	throw
catch	float	public	try
char	for	register	typedef
class	friend	return	union
const	goto	short	unsigned
continue	if	signed	virtual
default	inline	sizeof	void
delete	int	static	volatile
do	long	struct	while

Remark. **asm** is reserved for implementors to include a machine specific facility to pass information to an assembler. **extern** indicates that external linkage is to be made to this item. Obviously the placement of such an item must be known at compile time and hence must be implicitly static.

Basic Data Types of C++

The basic data types or primitive data types are as follows:

Type	May also be specified as	Comment
char		Holds a character
unsigned char		Unsigned version of char
signed char		Signed version of char
int	signed int signed	A machine word that holds an integer number
unsigned int	unsigned	Unsigned version of int
short	signed short int signed short	May have less precision than an int
unsigned short	unsigned short int	Unsigned version of short
long	long int	May have more precision than an int
unsigned long	unsigned long int	Unsigned version of long
long int	signed long int	
float		A number held in floating point form
double		May have more precision than a float
long double		May have more precision than a double

Note: A float, double and long double are stored as a floating point number. The rest of the basic data types are stored as an exact quantity.

The unsigned types will be able to store a larger positive number than their signed types.

The precision of items declared with these data types may vary, depending on the compiler or machine used.

The representation of char may be either signed or unsigned. This is to allow implementors the choice of the architectural representation of a char.

As can be seen from the table above, there is no basic data type for boolean values. C++ like C before, uses integer values to represent true and false. Newer C++ compilers have a boolean data type called bool.

Truth value	C++ delivers	C++ takes a truth value
true	1	Any value other than 0
false	0	0

C++ Operators

The following *precedence table* shows a summary of C++ operators in order of decreasing precedence. Each box holds operators of the same level of precedence.

For example

```
int u, x, y, z;  
x = 3; y = 9; z = 2;  
u = x + y % z;
```

firstly evaluates the remainder of $y\%z$ and then adds this to x and assigns the result to u . Another example is

```
*g.value      (*g).value
```

The member selection operator `.` has higher precedence than the dereferencing operator `*`. Hence `*g.value` dereferences `g.value`, whereas `(*g).value` dereferences `g` and then selects the member value of the object to which `g` points. The expression `(*g).value` can also be written as `g -> value`. The expression

```
int r = m%n/p;
```

first evaluates `m%n` then we divide and finally the assignment is done. Thus the right hand side evaluates from left to right.

The use of the operators given in following table will be illustrated with sample programs throughout this text. In C++ one can define operators for one's own data types. For example if one defines a data type for rational numbers, then one can define the addition, subtraction, multiplication etc. for this data type. This facility is called operator overloading. All operators can be overloaded (see discussion on operator overloading later in the text) except for

```
.      .*      ::      ?:
```

When overloading operators, one should bear in mind that the order of precedence and the syntax remains the same as that for the basic data types.

Operator	operator name	example
::	scope resolution	<i>class_name::member</i>
::	global	<i>::name</i>
++	preincrement	<i>++lvalue</i>
--	predecrement	<i>-- lvalue</i>
.	member selection	<i>object.name</i>
->	member selection	<i>pointer->member</i>
[]	array subscription	<i>pointer[expr]</i>
()	function call	<i>expr(expr_list)</i>
()	value construction	<i>type(expr_list)</i>
sizeof	size of object	<i>sizeof expr</i>
sizeof	size of type	<i>sizeof (type)</i>
-	one's complement	<i>~ expr</i>
!	not	<i>! expr</i>
+, -	unary plus and minus	<i>-expr</i> and <i>+expr</i>
&	address of	<i>&lvalue</i>
*	dereferencing	<i>*expr</i>
new	create (allocate memory)	<i>new type</i>
delete	deallocate pointer memory	<i>delete pointer</i>
delete[]	free array memory	<i>delete[] pointer</i>
()	cast (type conversion)	<i>(type) expr</i>
.*	member section	<i>object.*pointer-to-member</i>
->*	member section	<i>pointer->*pointer-to-member</i>
*, /, %	multiply, divide, modulo (remainder)	<i>expr / expr</i>
+, -	add, subtract	<i>expr + expr</i>
<<, >>	shift left, shift right	<i>expr << expr</i>
<, <=, >, >=	relational operators	<i>expr < expr</i>
==	equal	<i>expr == expr</i>
!=	not equal	<i>expr != expr</i>
&	bitwise AND	<i>expr & expr</i>
^	bitwise exclusive OR	<i>expr ^ expr</i>
	bitwise inclusive OR	<i>expr expr</i>
&&	logical AND	<i>expr && expr</i>
	logical inclusive OR	<i>expr expr</i>
? :	conditional expression	<i>expr ? expr : expr</i>
=	simple assignment	<i>lvalue = expr</i>
*, /=, +=, -=	multiply and assignment, ...	<i>lvalue *= expr</i>
<<=, >>=	shift left (right) and assign	<i>lvalue <<= expr</i>
&=, =, ^=	AND (OR, XOR) and assignment	<i>lvalue &= expr</i>
throw	throw exception	<i>throw expr</i>
,	comma (sequencing)	<i>expr , expr</i>
++	postfix increment	<i>lvalue++</i>
--	postfix decrement	<i>lvalue--</i>

Contents

1	Introduction	1
1.1	Aim of Object-Oriented Programming	1
1.1.1	Information Hiding	2
1.1.2	Inheritance	2
1.1.3	Polymorphism	3
1.1.4	Templates	3
1.1.5	Standard Template Library	3
1.2	Why C++ ?	4
2	C++ Basics	5
2.1	Introduction	5
2.2	A Simple C++ Program	7
2.3	Basic Data Types	9
2.4	Arithmetic Operations	11
2.5	ASCII Table and Types Conversion	14
2.6	Precedence Table	16
2.7	Pointers and References	18
2.8	Control Statements	21
2.8.1	Introduction	21
2.8.2	The if Statement	22
2.8.3	The for Loop, while Loop, do-while Loop	24
2.8.4	The switch Statement	26
2.9	Arrays	28
2.10	Strings	33
2.11	The sizeof Operator	37
2.12	The new and delete Operators	38
2.13	Arrays of Pointers	42
2.14	Logical AND, Logical OR and Logical NOT	46
2.15	Pass by Value, Pass by Reference	48
2.16	Command-Line Arguments	51
2.17	Bitwise Operations	55
2.18	Shift Operations	57
2.19	Passing a Function to a Function	59
2.20	Recursion	60
2.21	Inline Assembly Language	63

2.22	Time Header File	64
2.23	Random Numbers	66
2.24	Constants and Inline Functions	67
2.25	Jump Statements	69
2.26	The static Keyword	71
2.27	Structures	72
3	String Manipulations	75
3.1	Introduction	75
3.2	Digit Conversion to Character and String	76
3.3	Character in String	77
3.4	Append a Character to a String	78
3.5	Searching for a Character in a Given String	79
3.6	Delete a Character from a String	80
3.7	Replacement of a Character by a Character	81
3.8	Swapping Characters in a String	82
3.9	First n Characters from a String	83
3.10	Substring in String	84
3.11	Assignment and the Function strcpy	85
3.12	Permutations of a Word	86
3.13	String within String	88
3.14	Comparing Strings	90
3.15	Length of a String	92
3.16	Permutations of Characters in a String	93
3.17	Swapping Parts of a String	95
3.18	String Handling using Recursion	96
3.19	Concatenating Strings	98
3.20	Replacing a Substring in a String	100
3.21	Reversing the Characters in a String	102
3.22	Boyer and Moore's Algorithm	104
3.23	Subsets of a Given Set of Strings	107
3.24	Counting Characters and Digits in a Phrase	108
3.25	Counting Characters and Words in a Phrase	109
3.26	Centering Text	111
3.27	The Function getline	112
4	The Class Concept	113
4.1	Introduction	113
4.2	What is a Class ?	115
4.3	Constructors and Destructors	116
4.4	Copy Constructor	119
4.5	Operator Overloading	120
4.6	The Keyword this	121
4.7	Examples	123
4.7.1	Example 1.	123

4.7.2	Example 2.	126
4.7.3	Example 3.	128
4.7.4	Example 4.	130
4.7.5	Example 5.	133
4.8	Friend	135
4.9	Derivation and Inheritance	137
4.10	Virtual Functions	140
5	Function Templates	143
5.1	Introduction	143
5.2	Examples	144
6	Class Templates	151
6.1	Introduction	151
6.2	Examples	152
6.2.1	A Template Vector Class	152
6.2.2	A Template Stack Class	156
6.2.3	A Template Stack Class with Node	158
6.2.4	Two Generic Data Types	162
7	Sorting and Searching	163
7.1	Introduction	163
7.2	Largest Number in an Array	164
7.3	Quicksort and Bubblesort	165
7.4	Shellsort	167
7.5	Using the Function bsearch	171
7.6	Using the Function lsearch	172
7.7	Name Sorting	173
7.8	Name and Number Sorting Using Templates	177
7.9	Student Names and Student Numbers	181
7.10	Search for Names in a List	183
7.11	Names of Employees in a Table	184
7.12	The Divide-and-Conquer Methodology	186
7.13	Sorting Vectors	187
8	Useful Classes	189
8.1	Introduction	189
8.2	String Class	190
8.2.1	Introduction	190
8.2.2	A Simple String Class	191
8.2.3	Advanced String Classes	194
8.2.4	Standard Library and String Class	200
8.3	Vector Class	204
8.3.1	Introduction	204
8.3.2	A Simple Vector Class	205

8.3.3	Construction of an Advanced Vector Class	209
8.3.4	Listing of Vector Class	217
8.4	Matrix Class	225
8.4.1	Introduction	225
8.4.2	Listing of Matrix Class	228
8.5	Linked Lists	237
8.5.1	Introduction	237
8.5.2	Simple Linked Lists	241
8.5.3	Singly Linked Circular List	243
8.5.4	Recursive List	245
8.5.5	Linked List and Templates	248
8.5.6	Linked List and Iterators	250
8.5.7	Intrusive List	258
8.5.8	Generalized Lists	263
8.6	Binary Trees	269
8.6.1	Introduction	269
8.6.2	A Simple Binary Tree	270
8.6.3	Binary Trees and Templates	272
8.7	A Set Class	276
8.8	A Date and Month Class	282
8.8.1	Introduction	282
8.8.2	Listing of Complete Month and Date Classes	296
9	File Manipulations	305
9.1	Introduction	305
9.2	C Style File Manipulations	308
9.2.1	Output to File	308
9.2.2	Reading String from File	309
9.2.3	Word Count in File	310
9.2.4	File Searching Program	311
9.2.5	Counting Characters in a File	313
9.2.6	Class and Standard Output	316
9.2.7	The Functions fseek, fread, fwrite	318
9.2.8	The Function fscanf	321
9.3	C++ Style File Manipulation	323
9.3.1	Output to File	323
9.3.2	Reading String from File	324
9.3.3	String Replacement in File	325
9.3.4	Reading and Writing of File	327
9.3.5	Writing File to Another File	331
9.4	Binary File Operations	332
9.5	The Functions seekp and seekg	334
9.6	The Function isatty	335
9.7	The Function getenv	336

10 Applications in Finance	337
10.1 Introduction	337
10.2 Payroll	338
10.3 Loan and Interest	340
10.4 Amortization	343
10.5 Calculating the Loan Period	346
10.6 Periodic Savings	348
10.7 Compound Amount	352
10.8 The Floyd–Warshall Algorithm.	356
10.9 The Dijkstra Algorithm	359
10.10 Linear Programming and Simplex Method	362
11 Applications in Administration	375
11.1 Introduction	375
11.2 Names, Address and Inheritance	376
11.3 Line Editor and Nested Classes	379
11.4 Mergesort Applied to a List	386
11.5 Linked List of Strings	390
11.6 Data Encryption	394
11.7 Vector Class and a Dictionary	397
11.8 Spelling Checker	399
11.9 Huffman Code	403
11.10 Eliza	409
11.11 Counting the Letters in a Phrase	414
11.12 The Farmer, Wolf, Goat and Cabbage Problem	420
11.13 Roman Numbers	427
11.14 Day of the Week	430
11.15 Gregorian Calender	431
11.16 Records	436
11.17 Finite State Machine	443
11.18 Realtor	446
12 Applications in Statistics	453
12.1 Introduction	453
12.2 Arithmetic, Harmonic and Geometric Mean	454
12.3 Mean Value and the Standard Deviation	458
12.4 Histogram for Series of Numbers	461
12.5 Data Fitting by Least Squares	463
12.6 Curve Fitting	467
12.7 Pseudo-Random Number Generator	473
12.8 Correlation Coefficient	475
12.9 Autocorrelation Function	477
12.10 Random Number Generator and π	480

13 Exception Handling	485
13.1 Introduction	485
13.2 Error States	485
13.3 Exception Handling	486
14 The Standard Template Library	503
14.1 Introduction	503
14.2 The Namespace Concept	505
14.3 The Vector Class	506
14.4 The List Class	510
14.5 The Stack Class	512
14.6 The Queue Class	514
14.7 The Deque Class	516
14.8 The Bit Set Class	518
14.9 The Set Class	520
14.10The Map Class	522
14.11The Algorithm Class	525
Bibliography	527
Index	529