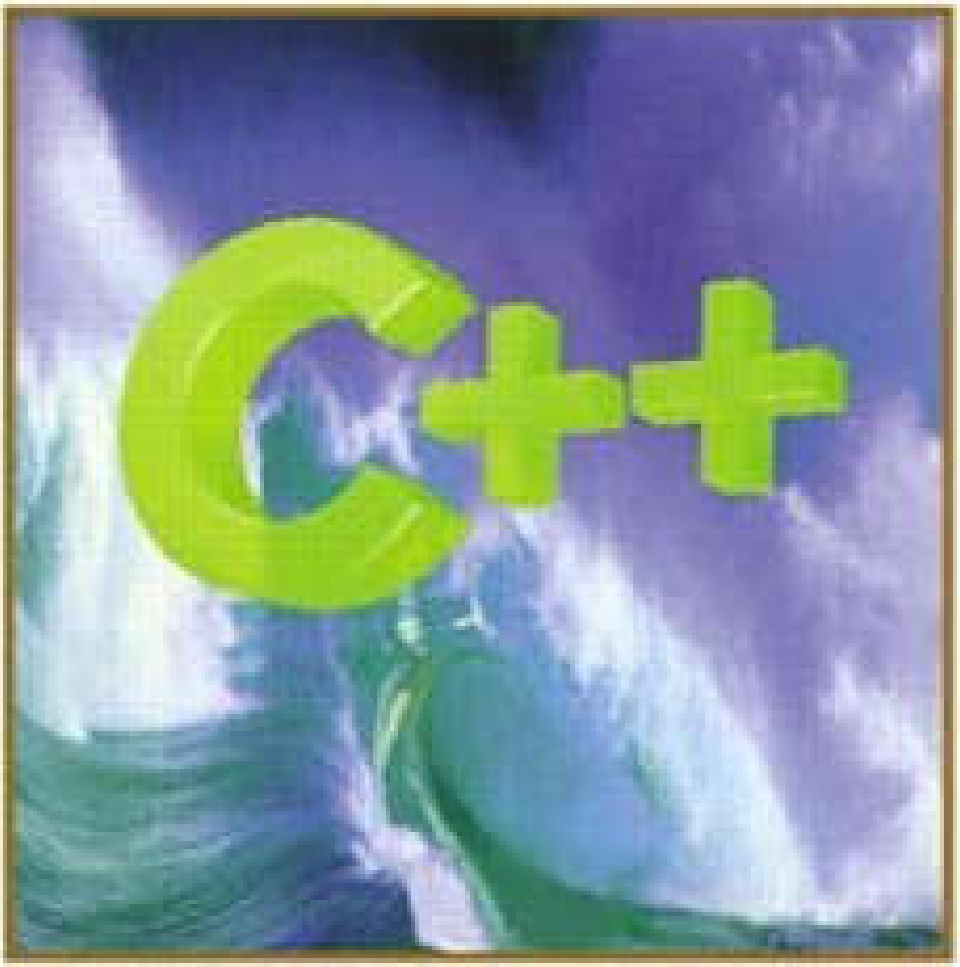
The C++ Programming Language

SPECIAL EDITION



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The Creator of C++

The C++ Programming Language

Third Edition

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Preface

Programming is understanding.
– Kristen Nygaard

I find using C++ more enjoyable than ever. C++'s support for design and programming has improved dramatically over the years, and lots of new helpful techniques have been developed for its use. However, C++ is not *just* fun. Ordinary practical programmers have achieved significant improvements in productivity, maintainability, flexibility, and quality in projects of just about any kind and scale. By now, C++ has fulfilled most of the hopes I originally had for it, and also succeeded at tasks I hadn't even dreamt of.

This book introduces standard C++† and the key programming and design techniques supported by C++. Standard C++ is a far more powerful and polished language than the version of C++ introduced by the first edition of this book. New language features such as namespaces, exceptions, templates, and run-time type identification allow many techniques to be applied more directly than was possible before, and the standard library allows the programmer to start from a much higher level than the bare language.

About a third of the information in the second edition of this book came from the first. This third edition is the result of a rewrite of even larger magnitude. It offers something to even the most experienced C++ programmer; at the same time, this book is easier for the novice to approach than its predecessors were. The explosion of C++ use and the massive amount of experience accumulated as a result makes this possible.

The definition of an extensive standard library makes a difference to the way C++ concepts can be presented. As before, this book presents C++ independently of any particular implementation, and as before, the tutorial chapters present language constructs and concepts in a ''bottom up'' order so that a construct is used only after it has been defined. However, it is much easier to use a well-designed library than it is to understand the details of its implementation. Therefore, the standard library can be used to provide realistic and interesting examples well before a reader can be assumed to understand its inner workings. The standard library itself is also a fertile source of programming examples and design techniques.

† ISO/IEC 14882, Standard for the C++ Programming Language.

This book presents every major C++ language feature and the standard library. It is organized around language and library facilities. However, features are presented in the context of their use. That is, the focus is on the language as the tool for design and programming rather than on the language in itself. This book demonstrates key techniques that make C++ effective and teaches the fundamental concepts necessary for mastery. Except where illustrating technicalities, examples are taken from the domain of systems software. A companion, *The Annotated C++ Language Standard*, presents the complete language definition together with annotations to make it more comprehensible.

The primary aim of this book is to help the reader understand how the facilities offered by C++ support key programming techniques. The aim is to take the reader far beyond the point where he or she gets code running primarily by copying examples and emulating programming styles from other languages. Only a good understanding of the ideas behind the language facilities leads to mastery. Supplemented by implementation documentation, the information provided is sufficient for completing significant real-world projects. The hope is that this book will help the reader gain new insights and become a better programmer and designer.

Acknowledgments

In addition to the people mentioned in the acknowledgement sections of the first and second editions, I would like to thank Matt Austern, Hans Boehm, Don Caldwell, Lawrence Crowl, Alan Feuer, Andrew Forrest, David Gay, Tim Griffin, Peter Juhl, Brian Kernighan, Andrew Koenig, Mike Mowbray, Rob Murray, Lee Nackman, Joseph Newcomer, Alex Stepanov, David Vandevoorde, Peter Weinberger, and Chris Van Wyk for commenting on draft chapters of this third edition. Without their help and suggestions, this book would have been harder to understand, contained more errors, been slightly less complete, and probably been a little bit shorter.

I would also like to thank the volunteers on the C++ standards committees who did an immense amount of constructive work to make C++ what it is today. It is slightly unfair to single out individuals, but it would be even more unfair not to mention anyone, so I'd like to especially mention Mike Ball, Dag Brück, Sean Corfield, Ted Goldstein, Kim Knuttila, Andrew Koenig, Josée Lajoie, Dmitry Lenkov, Nathan Myers, Martin O'Riordan, Tom Plum, Jonathan Shopiro, John Spicer, Jerry Schwarz, Alex Stepanov, and Mike Vilot, as people who each directly cooperated with me over some part of C++ and its standard library.

Murray Hill, New Jersey *Bjarne Stroustrup*

Preface to the Second Edition

The road goes ever on and on.
– Bilbo Baggins

As promised in the first edition of this book, C++ has been evolving to meet the needs of its users. This evolution has been guided by the experience of users of widely varying backgrounds working in a great range of application areas. The C++ user-community has grown a hundredfold during the six years since the first edition of this book; many lessons have been learned, and many techniques have been discovered and/or validated by experience. Some of these experiences are reflected here.

The primary aim of the language extensions made in the last six years has been to enhance C++ as a language for data abstraction and object-oriented programming in general and to enhance it as a tool for writing high-quality libraries of user-defined types in particular. A ''high-quality library,'' is a library that provides a concept to a user in the form of one or more classes that are convenient, safe, and efficient to use. In this context, *safe* means that a class provides a specific type-safe interface between the users of the library and its providers; *efficient* means that use of the class does not impose significant overheads in run-time or space on the user compared with hand-written C code.

This book presents the complete C++ language. Chapters 1 through 10 give a tutorial introduction; Chapters 11 through 13 provide a discussion of design and software development issues; and, finally, the complete C++ reference manual is included. Naturally, the features added and resolutions made since the original edition are integral parts of the presentation. They include refined overloading resolution, memory management facilities, and access control mechanisms, type-safe linkage, ***const*** and ***static*** member functions, abstract classes, multiple inheritance, templates, and exception handling.

C++ is a general-purpose programming language; its core application domain is systems programming in the broadest sense. In addition, C++ is successfully used in many application areas that are not covered by this label. Implementations of C++ exist from some of the most modest microcomputers to the largest supercomputers and for almost all operating systems. Consequently, this book describes the C++ language itself without trying to explain a particular implementation, programming environment, or library.

This book presents many examples of classes that, though useful, should be classified as ''toys.'' This style of exposition allows general principles and useful techniques to stand out more

clearly than they would in a fully elaborated program, where they would be buried in details. Most of the useful classes presented here, such as linked lists, arrays, character strings, matrices, graphics classes, associative arrays, etc., are available in ''bulletproof'' and/or ''goldplated'' versions from a wide variety of commercial and non-commercial sources. Many of these ''industrial strength'' classes and libraries are actually direct and indirect descendants of the toy versions found here.

This edition provides a greater emphasis on tutorial aspects than did the first edition of this book. However, the presentation is still aimed squarely at experienced programmers and endeavors not to insult their intelligence or experience. The discussion of design issues has been greatly expanded to reflect the demand for information beyond the description of language features and their immediate use. Technical detail and precision have also been increased. The reference manual, in particular, represents many years of work in this direction. The intent has been to provide a book with a depth sufficient to make more than one reading rewarding to most programmers. In other words, this book presents the C++ language, its fundamental principles, and the key techniques needed to apply it. Enjoy!

Acknowledgments

In addition to the people mentioned in the acknowledgements section in the preface to the first edition, I would like to thank Al Aho, Steve Buroff, Jim Coplien, Ted Goldstein, Tony Hansen, Lorraine Juhl, Peter Juhl, Brian Kernighan, Andrew Koenig, Bill Leggett, Warren Montgomery, Mike Mowbray, Rob Murray, Jonathan Shopiro, Mike Vilot, and Peter Weinberger for commenting on draft chapters of this second edition. Many people influenced the development of C++ from 1985 to 1991. I can mention only a few: Andrew Koenig, Brian Kernighan, Doug McIlroy, and Jonathan Shopiro. Also thanks to the many participants of the ''external reviews'' of the reference manual drafts and to the people who suffered through the first year of X3J16.

Murray Hill, New Jersey *Bjarne Stroustrup*

Preface to the First Edition

Language shapes the way we think,
and determines what we can think about.
– B.L.Whorf

C++ is a general purpose programming language designed to make programming more enjoyable for the serious programmer. Except for minor details, C++ is a superset of the C programming language. In addition to the facilities provided by C, C++ provides flexible and efficient facilities for defining new types. A programmer can partition an application into manageable pieces by defining new types that closely match the concepts of the application. This technique for program construction is often called *data abstraction.* Objects of some user-defined types contain type information. Such objects can be used conveniently and safely in contexts in which their type cannot be determined at compile time. Programs using objects of such types are often called *object based*. When used well, these techniques result in shorter, easier to understand, and easier to maintain programs.

The key concept in C++ is *class*. A class is a user-defined type. Classes provide data hiding, guaranteed initialization of data, implicit type conversion for user-defined types, dynamic typing, user-controlled memory management, and mechanisms for overloading operators. C++ provides much better facilities for type checking and for expressing modularity than C does. It also contains improvements that are not directly related to classes, including symbolic constants, inline substitution of functions, default function arguments, overloaded function names, free store management operators, and a reference type. C++ retains C's ability to deal efficiently with the fundamental objects of the hardware (bits, bytes, words, addresses, etc.). This allows the user-defined types to be implemented with a pleasing degree of efficiency.

C++ and its standard libraries are designed for portability. The current implementation will run on most systems that support C. C libraries can be used from a C++ program, and most tools that support programming in C can be used with C++.

This book is primarily intended to help serious programmers learn the language and use it for nontrivial projects. It provides a complete description of C++, many complete examples, and many more program fragments.