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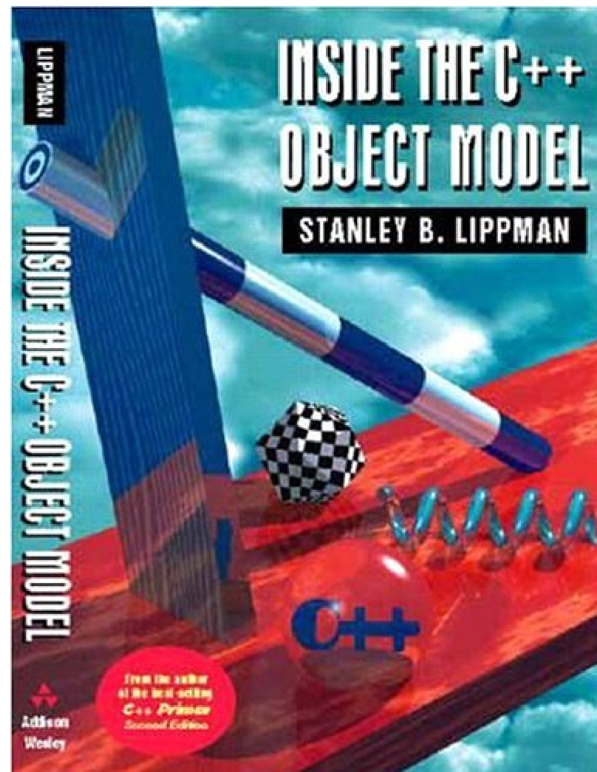

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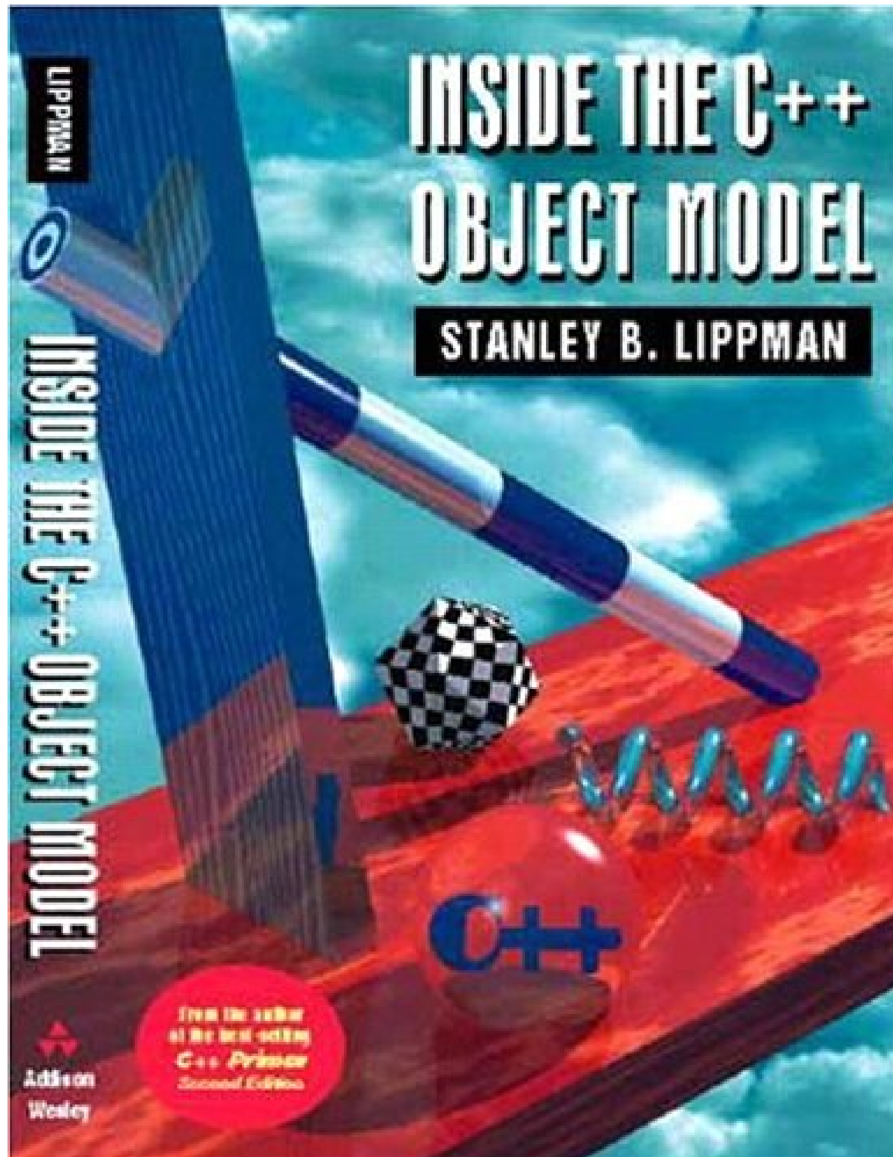

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Inside The C++ Object Model By Stanley B. Lippman Just how a straightforward suggestion by reading can improve you to be an effective person? Reading Inside The C++ Object Model By Stanley B. Lippman is a very simple activity. However, just how can lots of people be so lazy to check out? They will favor to spend their free time to talking or hanging out. When as a matter of fact, checking out Inside The C++ Object Model By Stanley B. Lippman will certainly give you more opportunities to be successful finished with the hard works.

Amazon.com Review
Bestselling author Stanley B. Lippman's Inside the C++ Model provides valuable insight into some of the internal workings of the C++ language. This book is a product of a decade of research at Bell Labs (where Lippman worked with C++ inventor Bjarne Stroustrup) and Lippman's considerable C++ expertise. Written with the experienced C++ programmer in mind, this book looks at how key language features are implemented underneath the hood and provides some guidelines when designing C++ classes.

This title first examines how C++ objects work--showing the differences between C++ structures and classes. The author looks carefully at the varieties of C++ constructors, including default and copy constructors, data members, and initialization.

Subsequent sections cover inheritance, including virtual inheritance, and the inner details that will help you create effective and robust data types. The author frequently points out inefficiencies (and efficiencies) that can occur when instantiating objects. The book closes with a tour of more advanced C++ language features, such as templates, exception handling, and run-time type information. This book can help make you the resident C++ language expert at your programming shop. --Richard Dragan

Review
Read the full review for this book.

Inside the C++ Object Model is aimed at those developers who routinely use C++ but feel the discomfort of not really knowing the underlying weight of many common operations they perform or constructs they peruse.

A particularly fit subset of these programmers is made up of the hardcore plumbers who pay their bills writing C++-based programming tools and libraries, or those who assume the uneasy role of the "official code optimizer" in a medium-to-large development team. Each of these programmers are going to immensely appreciate the intensive coverage of the object-oriented features offered by the language, their run-time overhead (in terms of execution time and binary size), and their influence in compilation times. This knowledge constitutes a major aid when it comes time to decide whether a certain language feature fits your needs without breaking your requirements. Moreover, along the way the text is sprinkled with

interesting anecdotes explaining why certain common myths regarding C++ are nothing more than unfounded rant. --Davide Marcato, Dr. Dobb's Electronic Review of Computer Books -- Dr. Dobb's Electronic Review of Computer Books

From the Inside Flap

For nearly a decade within Bell Laboratories, I labored at implementing C++. First it was on cfront, Bjarne Stroustrup's original C++ implementation (from Release 1.1 back in 1986 through Release 3.0, made available in September 1991). Then it was on what became known internally as the Simplifier, the C++ Object Model component of the Foundation project. It was during the Simplifier's design period that I conceived of and began working on this book.

What was the Foundation project? Under Bjarne's leadership, a small group of us within Bell Laboratories was exploring solutions to the problems of large-scale programming using C++. The Foundation was an effort to define a new development model for the construction of large systems (again, using C++ only; we weren't providing a multilingual solution). It was an exciting project, both for the work we were doing and for the people doing the work: Bjarne, Andy Koenig, Rob Murray, Martin Carroll, Judy Ward, Steve Buroff, Peter Juhl, and myself. Barbara Moo was supervising the gang of us other than Bjarne and Andy. Barbara used to say that managing a software group was like herding a pride of cats.

We thought of the Foundation as a kernel upon which others would layer an actual development environment for users, tailoring it to a UNIX or Smalltalk model as desired. Internally, we called it Grail, as in the quest for, etc. (It seems a Bell Laboratories tradition to mock one's most serious intentions.)

Grail provided for a persistent, semantic-based representation of the program using an object-oriented hierarchy Rob Murray developed and named ALF. Within Grail, the traditional compiler was factored into separate executables. The parser built up the ALF representation. Each of the other components (type checking, simplification, and code generation) and any tools, such as a browser, operated on (and possibly augmented) a centrally stored ALF representation of the program. The Simplifier is the part of the compiler between type checking and code generation. (Bjarne came up with the name Simplifier; it is a phase of the original cfront implementation.)

What does a Simplifier do between type checking and code generation? It transforms the internal program representation. There are three general flavors of transformations required by any object model component: Implementation-dependent transformations. These are implementation-specific aspects and vary across compilers. Under ALF, they involved the transformations of what we called "tentative" nodes. For example, when the parser sees the expression
fct();it doesn't know if this is (a) an invocation of a function represented or pointed to by fct or (b) the application of an overloaded call operator on a class object fct. By default, the expression is represented as a function call. The Simplifier rewrites and replaces the call subtree when case (b) applies.Language semantics transformations. These include constructor/destructor synthesis and augmentation, memberwise initialization and memberwise copy support, and the insertion within program code of conversion operators, temporaries, and constructor/destructor calls.Code and object model transformations. These include support for virtual functions, virtual base classes and inheritance in general, operators new and delete, arrays of class objects, local static class instances, and the static initialization of global objects with nonconstant expressions. An implementation goal I aimed for in the Simplifier was to provide an Object Model hierarchy in which the object implementation was a virtual interface supporting multiple object models.

These last two categories of transformations form the basis of this book. Does this mean this book is written for compiler writers? No, absolutely not. It is written by a (former) compiler writer (that's me) for

intermediate to advanced C++ programmers (ideally, that's you). The assumption behind this book is that the programmer, by understanding the underlying C++ Object Model, can write programs that are both less error prone and more efficient.What Is the C++ Object Model?

There are two aspects to the C++ Object Model:The direct support for object-oriented programming provided within the languageThe underlying mechanisms by which this support is implemented

The language level support is pretty well covered in my C++ Primer and in other books on C++. The second aspect is barely touched on in any current text, with the exception of brief discussions within ELLIS90 and STROUP94. It is this second aspect of the C++ Object Model that is the primary focus of this book. (In that sense, I consider this text to form a bookend to my C++ Primer, much as my MFA and MS degrees provide a "fearful symmetry" to my education.) The language covered within the text is the draft Standard C++ as of the winter 1995 meeting of the committee. (Except for some minor details, this should reflect the final form of the language.)

The first aspect of the C++ Object Model is invariant. For example, under C++ the complete set of virtual functions available to a class is fixed at compile time; the programmer cannot add to or replace a member of that set dynamically at runtime. This allows for extremely fast dispatch of a virtual invocation, although at the cost of runtime flexibility.

The underlying mechanisms by which to implement the Object Model are not prescribed by the language, although the semantics of the Object Model itself make some implementations more natural than others. Virtual function calls, for example, are generally resolved through an indexing into a table holding the address of the virtual functions. Must such a virtual table be used? No. An implementation is free to introduce an alternative mechanism. Moreover, if a virtual table is used, its layout, method of access, time of creation, and the other hundred details that must be decided, are all decisions left to each implementation. Having said that, however, I must also say that the general pattern of virtual function implementation across all current compilation systems is to use a class-specific virtual table of a fixed size that is constructed prior to program execution.

If the underlying mechanisms by which the C++ Object Model is implemented are not standardized, then one might ask, why bother to discuss them at all? The primary reason is because my experience has shown that if a programmer understands the underlying implementation model, the programmer can code more efficiently and with greater confidence. Determining when to provide a copy constructor, and when not, is not something one should guess at or have adjudicated by some language guru. It should come from an understanding of the Object Model.

A second reason for writing this book is to dispel the various misunderstandings surrounding C++ and its support of object-oriented programming. For example, here is an excerpt from a letter I received from someone wishing to introduce C++ into his programming environment:

I work with a couple of individuals who have not written and/or are completely unfamiliar with C++ and OO. One of the engineers who has been writing C code since 1985 feels very strongly that C++ is good only for user-type applications, but not server applications. What he is saying is to have a fast and efficient database level engine that it must be written in C compared to C++. He has identified that C++ is bulky and slow.C++, of course, is not inherently bulky and slow, although I've found this to be a common assumption among many C programmers. However, just saying that is not very convincing, particularly if the person saying it is perceived as a C++ partisan. This book is partially an attempt to lay out as precisely as I can the kinds of overhead that are and are not inherent in the various Object facilities such as inheritance, virtual functions, and pointers to class members.

Rather than answering the individual myself, I forwarded his letter to Steve Vinoski of Hewlett-Packard, with whom I had previously corresponded regarding the efficiency of C++. Here is an excerpt from his response:

I have heard a number of people over the years voice opinions similar to those of your colleagues. In every case, those opinions could be attributed to a lack of factual knowledge about the C++ language. Just last week I was chatting with an acquaintance who happens to work for an IC testing manufacturer, and he said they don't use C++ because "it does things behind your back." When I pressed him, he said that he understood that C++ calls malloc() and free() without the programmer knowing it. This is of course not true. It is this sort of "myth and legend" that leads to opinions such as those held by your colleagues....

Finding the right balance between abstraction and pragmatism requires knowledge, experience, and above all, thought. Using C++ well requires effort, but in my experience the returns on the invested effort can be quite high.

I like to think of this book, then, as my answer to this individual, and, I hope, a repository of knowledge to help put to rest many of the myths and legends surrounding C++.If the underlying mechanisms supporting the C++ Object Model vary both across implementations and over time, how can I possibly provide a general discussion of interest to any particular individual? Static initialization provides an interesting case in point.

Given a class X with a constructor, such as the following:class X{

friend istream&

operator>>(istream&, X&);public:X(int sz = 1024) { ptr = new char sz ; }...private:char *ptr;

};

and the declaration of a global object of class X, such as the following:X buf;main(){

// buf must be constructed at this point

cin >> setw(1024) >> buf;

...}

the C++ Object Model guarantees that the X constructor is applied to buf prior to the first user statement of main(). It does not, however, prescribe how that is to get done. The solution is called static initialization; the actual implementation depends on the degree of support provided by the environment.

The original cfront implementation not only presumed no environment support. It also presumed no explicit platform target. The only presumption was that of being under some variant of UNIX. Our solution, therefore, was specific only to UNIX: the presence of the nm command. The CC command (a UNIX shell script for portability) generated an executable, ran the nm command on the executable--thereby generating a new .c file--compiled the .c file, and then relinked the executable. (This was called the munch solution.) This did the job by trading compile-time efficiency for portability. Eventually, however, users chaffed under the compile-time overhead.

The next step was to provide a platform-specific solution: a COFF-based program (referred to as the patch solution) that directly examined and threaded the program executable, thus doing away with the need to run nm, compile, and relink. (COFF was the Common Object File Format for System V pre-Release 4 UNIX systems.) Both of these solutions are program-based, that is, within each .c file requiring static initialization

cfront generated an sti function to perform the required initializations. Both munch and patch solutions searched for functions bearing an sti prefix and arranged for them to be executed in some undefined order by a _main() library function inserted as the first statement of main().

In parallel with these releases of cfront, a System V COFF-specific C++ compiler was under development. Targeted for a specific platform and operating system, this compiler was able to effect a change in the System V link editor: a new initialize section that provided for the collection of objects needing static initialization. This extension of the link editor provides what I call an environment-based solution that is certainly superior to a program-based solution.

So any generalization based on the cfront program-based solution would be misleading. Why? Because as C++ has become a mainstream language, it has received more and more support for environment-based solutions. How is this book to maintain a balance, then? The book's strategy is as follows: If significantly different implementation models exist across C++ compilers, I present a discussion of at least two models. If subsequent implementation models evolved as an attempt to solve perceived problems with the original cfront model, as, for example, with support for virtual inheritance, I present a discussion of the historical evolution. Whenever I speak of the traditional implementation model, I mean, of course, Stroustrup's original design as reflected in cfront and which has provided a pattern of implementation that can still be seen today in all commercial implementations, even if only as a "reaction against."Organization of This Book

Chapter 1, Object Lessons, provides background on the object-based and object-oriented programming paradigms supported by C++. It includes a brief tour of the Object Model, illustrating the current prevailing industry implementation without looking too closely at multiple or virtual inheritance. (This is fleshed out in Chapters 3 and 4.)

Chapter 2, The Semantics of Constructors, discusses in detail how constructors work. It discusses when constructors are synthesized by the compiler and what that means in practical terms for your program's performance.

Chapters 3 through 5 contain the primary material of the book. There, the details of the C++ Object Model are discussed. Chapter 3, The Semantics of Data, looks at the handling of data members. Chapter 4, The Semantics of Function, focuses on the varieties of member functions, with a detailed look at virtual function support. Chapter 5, Semantics of Construction, Destruction, and Copy, deals with support of the class model and object lifetime. Program test data is discussed within each of these chapters, where our performance expectations are compared against actual performance as the representations move from an object-based to object-oriented solution.

Chapter 6, Runtime Semantics, looks at some of the Object Model behavior at runtime, including the life and death of temporary objects and the support of operators new and delete.

Chapter 7, On the Cusp of the Object Model, focuses on exception handling, template support, and runtime type identification.The Intended Audience

This book is primarily a tutorial, although it is aimed at the intermediate C++ programmer rather than the novice. I have attempted to provide sufficient context to make it understandable to anyone who has had some prior exposure to C++--for example, someone who has read my C++ Primer--and some experience in C++ programming. The ideal reader, however, has been programming in C++ for a few years and wants to better understand what is actually going on "under the hood." Portions of the material should be of interest even to the advanced C++ programmer, such as the generation of temporaries and the details of the named return value optimization. At least, this has proved to be so in the various public presentations of this material I have given as it has evolved.A Note on Program Examples and Program Execution

The use of program code in this text serves two primary purposes:To provide concrete illustrations of the various aspects of the C++ Object Model under discussionTo provide test cases by which to measure the relative cost of various language features

In neither case is the code intended to represent models of production-quality programming. I am not, for example, suggesting that a real 3D graphics library represents a 3D point using a virtual inheritance hierarchy (although one can be found in POKOR94).

All the test programs in the text were compiled and executed on an SGI Indigo2xL running version 5.2 of SGI's UNIX operating system under both its CC and NCC compilers. CC is cfront Release 3.0.1 (it generates C code, which a C compiler then recompiles into an executable). NCC is version 2.19 of the Edison Design Group's C++ front-end with a code generator supplied by SGI. The times were measured as the average user time reported by the UNIX timex command and represent 10 million iterations of the test function or statement block.

While the use of these two compilers on the xL hardware might strike the reader as somewhat esoteric, I feel doing so serves the book's purposes quite well. Both cfront and now the Edison Design Group's front-end (reportedly characterized by Bjarne as the son of cfront) are not platform specific. Rather, they are generic implementations licensed to over 34 computer manufacturers (including Cray, SGI, and Intel) and producers of software environments (including Centerline and Novell, which is the former UNIX Software Laboratories). Performance measurements are intended not to provide a benchmark of current compilation systems but to provide a measure of the relative costs of the various features of the C++ Object Model. Benchmark performance numbers can be found in nearly any "compiler shoot-out" product review in the trade press.Acknowledgments

One reason people write books is to set down and share their expertise with others. A second, more selfish reason is to enlarge on and fine tune that expertise. A third is to provide for the public acknowledgment of those who provide the foundation for one's work.

I owe a deep debt of gratitude to many former colleagues at Bell Laboratories without whose encouragement and insight little or nothing of this work could have been accomplished. In particular, Barbara Moo, Andy Koenig, and Bjarne Stroustrup have challenged and supported me throughout the years. Warm appreciation also goes to the Grail gang--Steve Buroff, Martin Carroll, Rob Murray, and Judy Ward--which has been a foundation for many years.

Michael Ball, now at SunPro, generously shared his expertise both through e-mail exchanges and an in-depth review of the text. Doug Schmidt, Cay Horstmann, and Steve Clamage also provided tough, thoughtful reviews of the manuscript that were invaluable in helping me push the manuscript's development forward. Jonathan Shopiro taught me a great deal while we worked together at Bell Laboratories; nuggets of his insight are scattered throughout the text. JoseE Lajoie fielded all too many questions about Standard C++ both with astounding patience and fearful insight.

In addition, I'd like to acknowledge my current foundation here at Walt Disney Feature Animation: Michael Blum, Nhi Casey, Shyh-Chyuan Huang, Scott Dolim, Elena Driskill, Ed Leonard, David Remba, Cary Sandvig, and Dave Tonnesen. Chyuan, Scott, and Elena provided thoughtful readings on various versions of the text. Appreciation also goes to M. J. Turner, Kiran Joshi, Scott Johnston, Marcus Hobbs, and, finally, to the Technology Division management of Dean Schiller and Paul Yanover. They have all helped to make my first year here at Disney sparkle a bit more brightly.

This material has been given at a great many public presentations during the more than two years I have worked on it. These include ACM-sponsored lectures in both Silicon Valley and Los Angeles; two

presentations in Tel Aviv sponsored by Sela (with particular thanks to Anna); talks at SIGS Conferences: Object Expo London, Object Expo New York, and C++ World; a tutorial at the 1994 ACM Sigplan Conference on Compiler Construction; at the 1994 IBM-sponsored Cascon Conference; and as part of my C++ Short Course sponsored by UCLA Extension. The resultant feedback has proved of immense help in crafting and revising the material.

Deep thanks also goes to my editor, Debbie Lafferty, who provided both sound counsel and unflagging support and always showed the good sense to laugh at my jokes.Finally, I'd like to extend my appreciation to Rick Friedman, founder and President of Sigs Publications, publisher of the C++ Report, for his support and vision while I was editor of that magazine from mid-1992 through 1995. The C++ Report was and remains the best timely source of high-quality technical information on C++. Portions of this text were originally published as columns in the magazine while I was editor.References

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Inside The C++ Object Model By Stanley B. Lippman. In undergoing this life, many individuals always attempt to do and obtain the finest. New understanding, encounter, driving lesson, and also every little thing that can boost the life will certainly be done. However, numerous individuals in some cases really feel puzzled to obtain those things. Feeling the limited of encounter as well as sources to be better is one of the lacks to possess. Nonetheless, there is a really simple thing that could be done. This is exactly what your instructor always manoeuvres you to do this one. Yeah, reading is the response. Reviewing an e-book as this Inside The C++ Object Model By Stanley B. Lippman and various other recommendations can enhance your life quality. How can it be?

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INSIDE THE C++ OBJECT MODEL BY STANLEY B. LIPPMAN PDF

Aimed at the beginner/intermediate C++ programmer who wants to understand the semantic implications of the C++ object model and how the model affects their programs, Inside the C++ Object Model explains where overhead costs reside, and what they actually consist of.

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- 304 pages

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From the Inside Flap

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What was the Foundation project? Under Bjarne's leadership, a small group of us within Bell Laboratories was exploring solutions to the problems of large-scale programming using C++. The Foundation was an effort to define a new development model for the construction of large systems (again, using C++ only; we weren't providing a multilingual solution). It was an exciting project, both for the work we were doing and for the people doing the work: Bjarne, Andy Koenig, Rob Murray, Martin Carroll, Judy Ward, Steve Buroff, Peter Juhl, and myself. Barbara Moo was supervising the gang of us other than Bjarne and Andy. Barbara used to say that managing a software group was like herding a pride of cats.

We thought of the Foundation as a kernel upon which others would layer an actual development environment for users, tailoring it to a UNIX or Smalltalk model as desired. Internally, we called it Grail, as in the quest for, etc. (It seems a Bell Laboratories tradition to mock one's most serious intentions.)

Grail provided for a persistent, semantic-based representation of the program using an object-oriented hierarchy Rob Murray developed and named ALF. Within Grail, the traditional compiler was factored into separate executables. The parser built up the ALF representation. Each of the other components (type checking, simplification, and code generation) and any tools, such as a browser, operated on (and possibly augmented) a centrally stored ALF representation of the program. The Simplifier is the part of the compiler between type checking and code generation. (Bjarne came up with the name Simplifier; it is a phase of the original cfront implementation.)

What does a Simplifier do between type checking and code generation? It transforms the internal program representation. There are three general flavors of transformations required by any object model component: Implementation-dependent transformations. These are implementation-specific aspects and vary across compilers. Under ALF, they involved the transformations of what we called "tentative" nodes. For example, when the parser sees the expression
fct();it doesn't know if this is (a) an invocation of a function represented or pointed to by fct or (b) the application of an overloaded call operator on a class object fct. By default, the expression is represented as a function call. The Simplifier rewrites and replaces the call subtree when case (b) applies.Language semantics transformations. These include constructor/destructor synthesis and augmentation, memberwise initialization and memberwise copy support, and the insertion within program code of conversion operators, temporaries, and constructor/destructor calls.Code and object model transformations. These include support for virtual functions, virtual base classes and inheritance in general, operators new and delete, arrays of class objects, local static class instances, and the static initialization of global objects with nonconstant expressions. An implementation goal I aimed for in the Simplifier was to provide an Object Model hierarchy in which the object implementation was a virtual interface supporting multiple object models.

These last two categories of transformations form the basis of this book. Does this mean this book is written for compiler writers? No, absolutely not. It is written by a (former) compiler writer (that's me) for intermediate to advanced C++ programmers (ideally, that's you). The assumption behind this book is that the programmer, by understanding the underlying C++ Object Model, can write programs that are both less error prone and more efficient.What Is the C++ Object Model?

There are two aspects to the C++ Object Model:The direct support for object-oriented programming provided within the languageThe underlying mechanisms by which this support is implemented

The language level support is pretty well covered in my C++ Primer and in other books on C++. The second aspect is barely touched on in any current text, with the exception of brief discussions within ELLIS90 and STROUP94. It is this second aspect of the C++ Object Model that is the primary focus of this book. (In that sense, I consider this text to form a bookend to my C++ Primer, much as my MFA and MS degrees provide a "fearful symmetry" to my education.) The language covered within the text is the draft Standard C++ as of the winter 1995 meeting of the committee. (Except for some minor details, this should reflect the final form of the language.)

The first aspect of the C++ Object Model is invariant. For example, under C++ the complete set of virtual functions available to a class is fixed at compile time; the programmer cannot add to or replace a member of that set dynamically at runtime. This allows for extremely fast dispatch of a virtual invocation, although at the cost of runtime flexibility.

The underlying mechanisms by which to implement the Object Model are not prescribed by the language, although the semantics of the Object Model itself make some implementations more natural than others. Virtual function calls, for example, are generally resolved through an indexing into a table holding the address of the virtual functions. Must such a virtual table be used? No. An implementation is free to introduce an alternative mechanism. Moreover, if a virtual table is used, its layout, method of access, time of creation, and the other hundred details that must be decided, are all decisions left to each implementation. Having said that, however, I must also say that the general pattern of virtual function implementation across all current compilation systems is to use a class-specific virtual table of a fixed size that is constructed prior to program execution.

If the underlying mechanisms by which the C++ Object Model is implemented are not standardized, then one might ask, why bother to discuss them at all? The primary reason is because my experience has shown that if a programmer understands the underlying implementation model, the programmer can code more efficiently and with greater confidence. Determining when to provide a copy constructor, and when not, is not something one should guess at or have adjudicated by some language guru. It should come from an understanding of the Object Model.

A second reason for writing this book is to dispel the various misunderstandings surrounding C++ and its support of object-oriented programming. For example, here is an excerpt from a letter I received from someone wishing to introduce C++ into his programming environment:

I work with a couple of individuals who have not written and/or are completely unfamiliar with C++ and OO. One of the engineers who has been writing C code since 1985 feels very strongly that C++ is good only for user-type applications, but not server applications. What he is saying is to have a fast and efficient database level engine that it must be written in C compared to C++. He has identified that C++ is bulky and slow.C++, of course, is not inherently bulky and slow, although I've found this to be a common assumption among many C programmers. However, just saying that is not very convincing, particularly if the person saying it is perceived as a C++ partisan. This book is partially an attempt to lay out as precisely as I can the

kinds of overhead that are and are not inherent in the various Object facilities such as inheritance, virtual functions, and pointers to class members.

Rather than answering the individual myself, I forwarded his letter to Steve Vinoski of Hewlett-Packard, with whom I had previously corresponded regarding the efficiency of C++. Here is an excerpt from his response:

I have heard a number of people over the years voice opinions similar to those of your colleagues. In every case, those opinions could be attributed to a lack of factual knowledge about the C++ language. Just last week I was chatting with an acquaintance who happens to work for an IC testing manufacturer, and he said they don't use C++ because "it does things behind your back." When I pressed him, he said that he understood that C++ calls malloc() and free() without the programmer knowing it. This is of course not true. It is this sort of "myth and legend" that leads to opinions such as those held by your colleagues....

Finding the right balance between abstraction and pragmatism requires knowledge, experience, and above all, thought. Using C++ well requires effort, but in my experience the returns on the invested effort can be quite high.

I like to think of this book, then, as my answer to this individual, and, I hope, a repository of knowledge to help put to rest many of the myths and legends surrounding C++.If the underlying mechanisms supporting the C++ Object Model vary both across implementations and over time, how can I possibly provide a general discussion of interest to any particular individual? Static initialization provides an interesting case in point.

Given a class X with a constructor, such as the following:class X{

friend istream&

operator>>(istream&, X&);public:X(int sz = 1024) { ptr = new char sz ; }...private:char *ptr;

};

and the declaration of a global object of class X, such as the following:X buf;main(){

// buf must be constructed at this point

cin >> setw(1024) >> buf;

...}

the C++ Object Model guarantees that the X constructor is applied to buf prior to the first user statement of main(). It does not, however, prescribe how that is to get done. The solution is called static initialization; the actual implementation depends on the degree of support provided by the environment.

The original cfront implementation not only presumed no environment support. It also presumed no explicit platform target. The only presumption was that of being under some variant of UNIX. Our solution, therefore, was specific only to UNIX: the presence of the nm command. The CC command (a UNIX shell script for portability) generated an executable, ran the nm command on the executable--thereby generating a new .c file--compiled the .c file, and then relinked the executable. (This was called the munch solution.) This did the job by trading compile-time efficiency for portability. Eventually, however, users chaffed under the compile-time overhead.

The next step was to provide a platform-specific solution: a COFF-based program (referred to as the patch

solution) that directly examined and threaded the program executable, thus doing away with the need to run nm, compile, and relink. (COFF was the Common Object File Format for System V pre-Release 4 UNIX systems.) Both of these solutions are program-based, that is, within each .c file requiring static initialization cfront generated an sti function to perform the required initializations. Both munch and patch solutions searched for functions bearing an sti prefix and arranged for them to be executed in some undefined order by a _main() library function inserted as the first statement of main().

In parallel with these releases of cfront, a System V COFF-specific C++ compiler was under development. Targeted for a specific platform and operating system, this compiler was able to effect a change in the System V link editor: a new initialize section that provided for the collection of objects needing static initialization. This extension of the link editor provides what I call an environment-based solution that is certainly superior to a program-based solution.

So any generalization based on the cfront program-based solution would be misleading. Why? Because as C++ has become a mainstream language, it has received more and more support for environment-based solutions. How is this book to maintain a balance, then? The book's strategy is as follows: If significantly different implementation models exist across C++ compilers, I present a discussion of at least two models. If subsequent implementation models evolved as an attempt to solve perceived problems with the original cfront model, as, for example, with support for virtual inheritance, I present a discussion of the historical evolution. Whenever I speak of the traditional implementation model, I mean, of course, Stroustrup's original design as reflected in cfront and which has provided a pattern of implementation that can still be seen today in all commercial implementations, even if only as a "reaction against."Organization of This Book

Chapter 1, Object Lessons, provides background on the object-based and object-oriented programming paradigms supported by C++. It includes a brief tour of the Object Model, illustrating the current prevailing industry implementation without looking too closely at multiple or virtual inheritance. (This is fleshed out in Chapters 3 and 4.)

Chapter 2, The Semantics of Constructors, discusses in detail how constructors work. It discusses when constructors are synthesized by the compiler and what that means in practical terms for your program's performance.

Chapters 3 through 5 contain the primary material of the book. There, the details of the C++ Object Model are discussed. Chapter 3, The Semantics of Data, looks at the handling of data members. Chapter 4, The Semantics of Function, focuses on the varieties of member functions, with a detailed look at virtual function support. Chapter 5, Semantics of Construction, Destruction, and Copy, deals with support of the class model and object lifetime. Program test data is discussed within each of these chapters, where our performance expectations are compared against actual performance as the representations move from an object-based to object-oriented solution.

Chapter 6, Runtime Semantics, looks at some of the Object Model behavior at runtime, including the life and death of temporary objects and the support of operators new and delete.

Chapter 7, On the Cusp of the Object Model, focuses on exception handling, template support, and runtime type identification.The Intended Audience

This book is primarily a tutorial, although it is aimed at the intermediate C++ programmer rather than the novice. I have attempted to provide sufficient context to make it understandable to anyone who has had some prior exposure to C++--for example, someone who has read my C++ Primer--and some experience in C++ programming. The ideal reader, however, has been programming in C++ for a few years and wants to better understand what is actually going on "under the hood." Portions of the material should be of interest even to

the advanced C++ programmer, such as the generation of temporaries and the details of the named return value optimization. At least, this has proved to be so in the various public presentations of this material I have given as it has evolved.A Note on Program Examples and Program Execution

The use of program code in this text serves two primary purposes:To provide concrete illustrations of the various aspects of the C++ Object Model under discussionTo provide test cases by which to measure the relative cost of various language features

In neither case is the code intended to represent models of production-quality programming. I am not, for example, suggesting that a real 3D graphics library represents a 3D point using a virtual inheritance hierarchy (although one can be found in POKOR94).

All the test programs in the text were compiled and executed on an SGI Indigo2xL running version 5.2 of SGI's UNIX operating system under both its CC and NCC compilers. CC is cfront Release 3.0.1 (it generates C code, which a C compiler then recompiles into an executable). NCC is version 2.19 of the Edison Design Group's C++ front-end with a code generator supplied by SGI. The times were measured as the average user time reported by the UNIX timex command and represent 10 million iterations of the test function or statement block.

While the use of these two compilers on the xL hardware might strike the reader as somewhat esoteric, I feel doing so serves the book's purposes quite well. Both cfront and now the Edison Design Group's front-end (reportedly characterized by Bjarne as the son of cfront) are not platform specific. Rather, they are generic implementations licensed to over 34 computer manufacturers (including Cray, SGI, and Intel) and producers of software environments (including Centerline and Novell, which is the former UNIX Software Laboratories). Performance measurements are intended not to provide a benchmark of current compilation systems but to provide a measure of the relative costs of the various features of the C++ Object Model. Benchmark performance numbers can be found in nearly any "compiler shoot-out" product review in the trade press.Acknowledgments

One reason people write books is to set down and share their expertise with others. A second, more selfish reason is to enlarge on and fine tune that expertise. A third is to provide for the public acknowledgment of those who provide the foundation for one's work.

I owe a deep debt of gratitude to many former colleagues at Bell Laboratories without whose encouragement and insight little or nothing of this work could have been accomplished. In particular, Barbara Moo, Andy Koenig, and Bjarne Stroustrup have challenged and supported me throughout the years. Warm appreciation also goes to the Grail gang--Steve Buroff, Martin Carroll, Rob Murray, and Judy Ward--which has been a foundation for many years.

Michael Ball, now at SunPro, generously shared his expertise both through e-mail exchanges and an in-depth review of the text. Doug Schmidt, Cay Horstmann, and Steve Clamage also provided tough, thoughtful reviews of the manuscript that were invaluable in helping me push the manuscript's development forward. Jonathan Shopiro taught me a great deal while we worked together at Bell Laboratories; nuggets of his insight are scattered throughout the text. JoseE Lajoie fielded all too many questions about Standard C++ both with astounding patience and fearful insight.

In addition, I'd like to acknowledge my current foundation here at Walt Disney Feature Animation: Michael Blum, Nhi Casey, Shyh-Chyuan Huang, Scott Dolim, Elena Driskill, Ed Leonard, David Remba, Cary Sandvig, and Dave Tonnesen. Chyuan, Scott, and Elena provided thoughtful readings on various versions of the text. Appreciation also goes to M. J. Turner, Kiran Joshi, Scott Johnston, Marcus Hobbs, and, finally, to the Technology Division management of Dean Schiller and Paul Yanover. They have all helped to make my

first year here at Disney sparkle a bit more brightly.

This material has been given at a great many public presentations during the more than two years I have worked on it. These include ACM-sponsored lectures in both Silicon Valley and Los Angeles; two presentations in Tel Aviv sponsored by Sela (with particular thanks to Anna); talks at SIGS Conferences: Object Expo London, Object Expo New York, and C++ World; a tutorial at the 1994 ACM Sigplan Conference on Compiler Construction; at the 1994 IBM-sponsored Cascon Conference; and as part of my C++ Short Course sponsored by UCLA Extension. The resultant feedback has proved of immense help in crafting and revising the material.

Deep thanks also goes to my editor, Debbie Lafferty, who provided both sound counsel and unflagging support and always showed the good sense to laugh at my jokes.Finally, I'd like to extend my appreciation to Rick Friedman, founder and President of Sigs Publications, publisher of the C++ Report, for his support and vision while I was editor of that magazine from mid-1992 through 1995. The C++ Report was and remains the best timely source of high-quality technical information on C++. Portions of this text were originally published as columns in the magazine while I was editor.References

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Essential Reading for Real Time C++ Programmers
By Harvey Sugar
If you use C++ in real time environments, you need this book. Real time programmers need to understand "what is going on under the covers." This is really the only book I've found that explains it in depth.

Reading this book is important if you are trying to decide whether to code in C or C++. You need to understand the overhead of C++, where it comes from and, at times, how to avoid it.

When debugging an understanding of how the compiler translates C++ code into machine language is essential. Lippmans book does not delve into code generation but it does provide a framework for understanding how the C++ object model is represented in machine language.

I'll be the first to admit that Lippman can go off on to some arcane tangents. He can spend a few pages discussing details that really have minimal effect on code execution. But I'm willing to forgive these diversions because so much of his book has contributed to my understanding of C++ and how it works.

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INSIDE THE C++ OBJECT MODEL BY STANLEY B. LIPPMAN PDF

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Amazon.com Review
Bestselling author Stanley B. Lippman's Inside the C++ Model provides valuable insight into some of the internal workings of the C++ language. This book is a product of a decade of research at Bell Labs (where Lippman worked with C++ inventor Bjarne Stroustrup) and Lippman's considerable C++ expertise. Written with the experienced C++ programmer in mind, this book looks at how key language features are implemented underneath the hood and provides some guidelines when designing C++ classes.

This title first examines how C++ objects work--showing the differences between C++ structures and classes. The author looks carefully at the varieties of C++ constructors, including default and copy constructors, data members, and initialization.

Subsequent sections cover inheritance, including virtual inheritance, and the inner details that will help you create effective and robust data types. The author frequently points out inefficiencies (and efficiencies) that can occur when instantiating objects. The book closes with a tour of more advanced C++ language features, such as templates, exception handling, and run-time type information. This book can help make you the resident C++ language expert at your programming shop. --Richard Dragan

Review
Read the full review for this book.

Inside the C++ Object Model is aimed at those developers who routinely use C++ but feel the discomfort of not really knowing the underlying weight of many common operations they perform or constructs they peruse.

A particularly fit subset of these programmers is made up of the hardcore plumbers who pay their bills writing C++-based programming tools and libraries, or those who assume the uneasy role of the "official code optimizer" in a medium-to-large development team. Each of these programmers are going to immensely appreciate the intensive coverage of the object-oriented features offered by the language, their run-time overhead (in terms of execution time and binary size), and their influence in compilation times. This knowledge constitutes a major aid when it comes time to decide whether a certain language feature fits your needs without breaking your requirements. Moreover, along the way the text is sprinkled with interesting anecdotes explaining why certain common myths regarding C++ are nothing more than unfounded rant. --Davide Marcato, Dr. Dobb's Electronic Review of Computer Books -- Dr. Dobb's Electronic Review of Computer Books

From the Inside Flap

For nearly a decade within Bell Laboratories, I labored at implementing C++. First it was on cfront, Bjarne Stroustrup's original C++ implementation (from Release 1.1 back in 1986 through Release 3.0, made available in September 1991). Then it was on what became known internally as the Simplifier, the C++ Object Model component of the Foundation project. It was during the Simplifier's design period that I conceived of and began working on this book.

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The language level support is pretty well covered in my C++ Primer and in other books on C++. The second aspect is barely touched on in any current text, with the exception of brief discussions within ELLIS90 and STROUP94. It is this second aspect of the C++ Object Model that is the primary focus of this book. (In that sense, I consider this text to form a bookend to my C++ Primer, much as my MFA and MS degrees provide a "fearful symmetry" to my education.) The language covered within the text is the draft Standard C++ as of the winter 1995 meeting of the committee. (Except for some minor details, this should reflect the final form of the language.)

The first aspect of the C++ Object Model is invariant. For example, under C++ the complete set of virtual functions available to a class is fixed at compile time; the programmer cannot add to or replace a member of that set dynamically at runtime. This allows for extremely fast dispatch of a virtual invocation, although at the cost of runtime flexibility.

The underlying mechanisms by which to implement the Object Model are not prescribed by the language, although the semantics of the Object Model itself make some implementations more natural than others. Virtual function calls, for example, are generally resolved through an indexing into a table holding the address of the virtual functions. Must such a virtual table be used? No. An implementation is free to introduce an alternative mechanism. Moreover, if a virtual table is used, its layout, method of access, time of creation, and the other hundred details that must be decided, are all decisions left to each implementation. Having said that, however, I must also say that the general pattern of virtual function implementation across all current compilation systems is to use a class-specific virtual table of a fixed size that is constructed prior to program execution.

If the underlying mechanisms by which the C++ Object Model is implemented are not standardized, then one might ask, why bother to discuss them at all? The primary reason is because my experience has shown that if a programmer understands the underlying implementation model, the programmer can code more efficiently and with greater confidence. Determining when to provide a copy constructor, and when not, is not something one should guess at or have adjudicated by some language guru. It should come from an understanding of the Object Model.

A second reason for writing this book is to dispel the various misunderstandings surrounding C++ and its support of object-oriented programming. For example, here is an excerpt from a letter I received from someone wishing to introduce C++ into his programming environment:

I work with a couple of individuals who have not written and/or are completely unfamiliar with C++ and OO. One of the engineers who has been writing C code since 1985 feels very strongly that C++ is good only for user-type applications, but not server applications. What he is saying is to have a fast and efficient database level engine that it must be written in C compared to C++. He has identified that C++ is bulky and slow.C++, of course, is not inherently bulky and slow, although I've found this to be a common assumption among many C programmers. However, just saying that is not very convincing, particularly if the person saying it is perceived as a C++ partisan. This book is partially an attempt to lay out as precisely as I can the kinds of overhead that are and are not inherent in the various Object facilities such as inheritance, virtual functions, and pointers to class members.

Rather than answering the individual myself, I forwarded his letter to Steve Vinoski of Hewlett-Packard, with whom I had previously corresponded regarding the efficiency of C++. Here is an excerpt from his response:

I have heard a number of people over the years voice opinions similar to those of your colleagues. In every case, those opinions could be attributed to a lack of factual knowledge about the C++ language. Just last week I was chatting with an acquaintance who happens to work for an IC testing manufacturer, and he said they don't use C++ because "it does things behind your back." When I pressed him, he said that he understood that C++ calls malloc() and free() without the programmer knowing it. This is of course not true. It is this sort of "myth and legend" that leads to opinions such as those held by your colleagues....

Finding the right balance between abstraction and pragmatism requires knowledge, experience, and above all, thought. Using C++ well requires effort, but in my experience the returns on the invested effort can be quite high.

I like to think of this book, then, as my answer to this individual, and, I hope, a repository of knowledge to help put to rest many of the myths and legends surrounding C++.If the underlying mechanisms supporting the C++ Object Model vary both across implementations and over time, how can I possibly provide a general discussion of interest to any particular individual? Static initialization provides an interesting case in point.

Given a class X with a constructor, such as the following:class X{

friend istream&

operator>>(istream&, X&);public:X(int sz = 1024) { ptr = new char sz ; }...private:char *ptr;

};

and the declaration of a global object of class X, such as the following:X buf;main(){

// buf must be constructed at this point

cin >> setw(1024) >> buf;

...}

the C++ Object Model guarantees that the X constructor is applied to buf prior to the first user statement of main(). It does not, however, prescribe how that is to get done. The solution is called static initialization; the actual implementation depends on the degree of support provided by the environment.

The original cfront implementation not only presumed no environment support. It also presumed no explicit platform target. The only presumption was that of being under some variant of UNIX. Our solution, therefore, was specific only to UNIX: the presence of the nm command. The CC command (a UNIX shell script for portability) generated an executable, ran the nm command on the executable--thereby generating a new .c file--compiled the .c file, and then relinked the executable. (This was called the munch solution.) This did the job by trading compile-time efficiency for portability. Eventually, however, users chaffed under the compile-time overhead.

The next step was to provide a platform-specific solution: a COFF-based program (referred to as the patch solution) that directly examined and threaded the program executable, thus doing away with the need to run nm, compile, and relink. (COFF was the Common Object File Format for System V pre-Release 4 UNIX systems.) Both of these solutions are program-based, that is, within each .c file requiring static initialization cfront generated an sti function to perform the required initializations. Both munch and patch solutions searched for functions bearing an sti prefix and arranged for them to be executed in some undefined order by a _main() library function inserted as the first statement of main().

In parallel with these releases of cfront, a System V COFF-specific C++ compiler was under development. Targeted for a specific platform and operating system, this compiler was able to effect a change in the System V link editor: a new initialize section that provided for the collection of objects needing static initialization. This extension of the link editor provides what I call an environment-based solution that is certainly superior to a program-based solution.

So any generalization based on the cfront program-based solution would be misleading. Why? Because as C++ has become a mainstream language, it has received more and more support for environment-based solutions. How is this book to maintain a balance, then? The book's strategy is as follows: If significantly different implementation models exist across C++ compilers, I present a discussion of at least two models. If subsequent implementation models evolved as an attempt to solve perceived problems with the original cfront model, as, for example, with support for virtual inheritance, I present a discussion of the historical evolution. Whenever I speak of the traditional implementation model, I mean, of course, Stroustrup's original design as reflected in cfront and which has provided a pattern of implementation that can still be seen today in all commercial implementations, even if only as a "reaction against."Organization of This Book

Chapter 1, Object Lessons, provides background on the object-based and object-oriented programming paradigms supported by C++. It includes a brief tour of the Object Model, illustrating the current prevailing industry implementation without looking too closely at multiple or virtual inheritance. (This is fleshed out in Chapters 3 and 4.)

Chapter 2, The Semantics of Constructors, discusses in detail how constructors work. It discusses when constructors are synthesized by the compiler and what that means in practical terms for your program's performance.

Chapters 3 through 5 contain the primary material of the book. There, the details of the C++ Object Model are discussed. Chapter 3, The Semantics of Data, looks at the handling of data members. Chapter 4, The Semantics of Function, focuses on the varieties of member functions, with a detailed look at virtual function support. Chapter 5, Semantics of Construction, Destruction, and Copy, deals with support of the class model and object lifetime. Program test data is discussed within each of these chapters, where our performance expectations are compared against actual performance as the representations move from an object-based to object-oriented solution.

Chapter 6, Runtime Semantics, looks at some of the Object Model behavior at runtime, including the life and death of temporary objects and the support of operators new and delete.

Chapter 7, On the Cusp of the Object Model, focuses on exception handling, template support, and runtime type identification.The Intended Audience

This book is primarily a tutorial, although it is aimed at the intermediate C++ programmer rather than the novice. I have attempted to provide sufficient context to make it understandable to anyone who has had some prior exposure to C++--for example, someone who has read my C++ Primer--and some experience in C++ programming. The ideal reader, however, has been programming in C++ for a few years and wants to better understand what is actually going on "under the hood." Portions of the material should be of interest even to the advanced C++ programmer, such as the generation of temporaries and the details of the named return value optimization. At least, this has proved to be so in the various public presentations of this material I have given as it has evolved.A Note on Program Examples and Program Execution

The use of program code in this text serves two primary purposes:To provide concrete illustrations of the various aspects of the C++ Object Model under discussionTo provide test cases by which to measure the relative cost of various language features

In neither case is the code intended to represent models of production-quality programming. I am not, for example, suggesting that a real 3D graphics library represents a 3D point using a virtual inheritance hierarchy (although one can be found in POKOR94).

All the test programs in the text were compiled and executed on an SGI Indigo2xL running version 5.2 of SGI's UNIX operating system under both its CC and NCC compilers. CC is cfront Release 3.0.1 (it generates C code, which a C compiler then recompiles into an executable). NCC is version 2.19 of the Edison Design Group's C++ front-end with a code generator supplied by SGI. The times were measured as the average user time reported by the UNIX timex command and represent 10 million iterations of the test function or statement block.

While the use of these two compilers on the xL hardware might strike the reader as somewhat esoteric, I feel doing so serves the book's purposes quite well. Both cfront and now the Edison Design Group's front-end (reportedly characterized by Bjarne as the son of cfront) are not platform specific. Rather, they are generic implementations licensed to over 34 computer manufacturers (including Cray, SGI, and Intel) and producers of software environments (including Centerline and Novell, which is the former UNIX Software Laboratories). Performance measurements are intended not to provide a benchmark of current compilation systems but to provide a measure of the relative costs of the various features of the C++ Object Model. Benchmark performance numbers can be found in nearly any "compiler shoot-out" product review in the trade press.Acknowledgments

One reason people write books is to set down and share their expertise with others. A second, more selfish reason is to enlarge on and fine tune that expertise. A third is to provide for the public acknowledgment of those who provide the foundation for one's work.

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