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Information technology — Programming languages, their environments and system software interfaces — Technical Report on C++ Performance

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Foreword

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The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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ISO/IEC TR 18015, which is a Technical Report of type 3, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 22, *Programming languages, their environments and system software interfaces.*

Introduction

"Performance" has many aspects – execution speed, code size, data size, and memory footprint at run-time, or time and space consumed by the edit/compile/link process. It could even refer to the time necessary to find and fix code defects. Most people are primarily concerned with execution speed, although program footprint and memory usage can be critical for small embedded systems where the program is stored in ROM, or where ROM and RAM are combined on a single chip.

Efficiency has been a major design goal for C++ from the beginning, as has the principle of "zero overhead" for any feature that is not used in a program. It has been a guiding principle from the earliest days of C++ that "you don't pay for what you don't use".

Language features that are never used in a program should not have a cost in extra code size, memory size, or run-time. If there are places where C++ cannot guarantee zero overhead for unused features, this Technical Report will attempt to document them. It will also discuss ways in which compiler writers, library vendors, and programmers can minimize or eliminate performance penalties, and will discuss the trade-offs among different methods of implementation.

Programming for resource-constrained environments is another focus of this Technical Report Typically, programs that run into resource limits of some kind are either very large or very small. Very large programs, such as database servers, may run into limits of disk space or virtual memory. At the other extreme, an embedded application may be constrained to run in the ROM and RAM space provided by a single chip, perhaps a total of 64K of memory, or even smaller.

Apart from the issues of resource limits, some programs must interface with system hardware at a very low level. Historically the interfaces to hardware have been implemented as proprietary extensions to the compiler (often as macros). This has led to the situation that code has not been portable, even for programs written for a given environment, because each compiler for that environment has implemented different sets of extensions.

Participants

The following people contributed work to this Technical Report:

Dave Abrahams	Dietmar Kühl
Mike Ball	Jens Maurer
Walter Banks	Fusako Mitsuhashi
Greg Colvin	Hiroshi Monden
Embedded C++ Technical Committee (Japan)	Nathan Myers
Hiroshi Fukutomi	Masaya Obata
Lois Goldthwaite	Martin O'Riordan
Yenjo Han	Tom Plum
John Hauser	Dan Saks
Seiji Hayashida	Martin Sebor
Howard Hinnant	Bill Seymour
Brendan Kehoe	Bjarne Stroustrup
Robert Klarer	Detlef Vollmann
Jan Kristofferson	Willem Wakker

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1 Scope

The aim of this Technical Report is:

- to give the reader a model of time and space overheads implied by use of various C++ language and library features,

- to debunk widespread myths about performance problems,

- to present techniques for use of C++ in applications where performance matters, and

- to present techniques for implementing C++ Standard language and library facilities to yield efficient code.

As far as run-time and space performance are concerned, if you can afford to use C for an application, you can afford to use C++ in a style that uses C++'s facilities appropriately for that application.

This Technical Report first discusses areas where performance issues matter, such as various forms of embedded systems programming and high-performance numerical computation. After that, the main body of the Technical Report considers the basic cost of using language and library facilities, techniques for writing efficient code, and the special needs of embedded systems programming.

Performance implications of object-oriented programming are presented. This discussion rests on measurements of key language facilities supporting OOP, such as classes, class member functions, class hierarchies, virtual functions, multiple inheritance, and run-time type information (RTTI). It is demonstrated that, with the exception of RTTI, current C++ implementations can match hand-written low-level code for equivalent tasks. Similarly, the performance implications of generic programming using templates are discussed. Here, however, the emphasis is on techniques for effective use. Error handling using exceptions is discussed based on another set of measurements. Both time and space overheads are discussed. In addition, the predictability of performance of a given operation is considered.

The performance implications of IOStreams and Locales are examined in some detail and many generally useful techniques for time and space optimizations are discussed.

The special needs of embedded systems programming are presented, including ROMability and predictability. A separate chapter presents general C and C++ interfaces to the basic hardware facilities of embedded systems.

Additional research is continuing into techniques for producing efficient C++ libraries and programs. Please see the WG21 web site at www.open-std.org/jtc1/sc22/wg21 for example code from this Technical Report and pointers to other sites with relevant information.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 14882:2003, *Programming Languages – C++*.

Mentions of "the Standard" or "IS" followed by a clause or paragraph number refer to the above International Standard for C++. Section numbers not preceded by "IS" refer to locations within this Technical Report.