



BSI Standards Publication

Programming languages — C++ Extensions for ranges

National foreword

This Published Document is the UK implementation of ISO/IEC TS 21425:2017.

The UK participation in its preparation was entrusted to Technical Committee IST/5, Programming languages, their environments and system software interfaces.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2018
Published by BSI Standards Limited 2018

ISBN 978 0 580 52141 6

ICS 35.060

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 30 April 2018.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

TECHNICAL SPECIFICATION

ISO/IEC TS 21425

First edition
2017-11

Programming languages — C++ Extensions for ranges

Langages de programmation — Extensions C++ pour les «ranges»



Reference number
ISO/IEC TS 21425:2017(E)

© ISO/IEC 2017



COPYRIGHT PROTECTED DOCUMENT

© ISO/IEC 2017, Published in Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Foreword	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 General principles	2
4.1 Implementation compliance	2
4.2 Namespaces, headers, and modifications to standard classes	2
5 Statements	3
5.1 Iteration statements	3
6 Library introduction	4
6.1 General	4
6.2 Method of description (Informative)	4
6.3 Library-wide requirements	6
7 Concepts library	8
7.1 General	8
7.2 Header <code><experimental/ranges/concepts></code> synopsis	9
7.3 Core language concepts	11
7.4 Comparison concepts	16
7.5 Object concepts	18
7.6 Callable concepts	19
8 General utilities library	21
8.1 General	21
8.2 Utility components	21
8.3 Function objects	22
8.4 Metaprogramming and type traits	26
8.5 Tagged tuple-like types	30
9 Iterators library	34
9.1 General	34
9.2 Header <code><experimental/ranges/iterator></code> synopsis	34
9.3 Iterator requirements	42
9.4 Indirect callable requirements	50
9.5 Common algorithm requirements	52
9.6 Iterator primitives	54
9.7 Iterator adaptors	58
9.8 Stream iterators	86
10 Ranges library	94
10.1 General	94
10.2 <code>decay_copy</code>	94
10.3 Header <code><experimental/ranges/range></code> synopsis	94
10.4 Range access	95
10.5 Range primitives	97
10.6 Range requirements	98

11 Algorithms library	101
11.1 General	101
11.2 Tag specifiers	117
11.3 Non-modifying sequence operations	118
11.4 Mutating sequence operations	123
11.5 Sorting and related operations	133
12 Numerics library	146
12.1 Uniform random number generator requirements	146
A Compatibility features	147
A.1 General	147
A.2 Rvalue range access	147
A.3 Range-and-a-half algorithms	147
B Acknowledgements	149
C Compatibility	150
C.1 C++ and Ranges	150
C.2 Ranges and the Palo Alto TR (N3351)	151
Bibliography	153
Index	154
Index of library names	155

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 22, *Programming languages, their environments and system software interfaces*.

Programming languages — C++ Extensions for ranges

1 Scope

[intro.scope]

¹ This document describes extensions to the C++ Programming Language (2) that permit operations on ranges of data. These extensions include changes and additions to the existing library facilities as well as the extension of one core language facility. In particular, changes and extensions to the Standard Library include:

- (1.1) — The formulation of the foundational and iterator concept requirements using the syntax of the Concepts TS (2).
- (1.2) — Analogues of the Standard Library algorithms specified in terms of the new concepts.
- (1.3) — The loosening of the algorithm constraints to permit the use of *sentinels* to denote the end of a range and corresponding changes to algorithm return types where necessary.
- (1.4) — The addition of new concepts describing *range* and *view* abstractions; that is, objects with a begin iterator and an end sentinel.
- (1.5) — New algorithm overloads that take range objects.
- (1.6) — Support of *callable objects* (as opposed to *function objects*) passed as arguments to the algorithms.
- (1.7) — The addition of optional *projection* arguments to the algorithms to permit on-the-fly data transformations.
- (1.8) — Analogues of the iterator primitives and new primitives in support of the addition of sentinels to the library.
- (1.9) — Constrained analogues of the standard iterator adaptors and stream iterators that satisfy the new iterator concepts.
- (1.10) — New iterator adaptors (`counted_iterator` and `common_iterator`) and sentinels (`unreachable`).

² Changes to the core language include:

- (2.1) — the extension of the range-based `for` statement to support the new iterator range requirements (10.4).

³ This document does not specify constrained analogues of other parts of the Standard Library (e.g., the numeric algorithms), nor does it add range support to all the places that could benefit from it (e.g., the containers).

⁴ This document does not specify any new range views, actions, or facade or adaptor utilities; all are left as future work.

2 Normative references

[intro.refs]

¹ The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

- (1.1) — ISO/IEC 14882:2014, *Programming Languages - C++*
- (1.2) — ISO/IEC TS 19217:2015, *Programming Languages - C++ Extensions for Concepts*

ISO/IEC 14882:2014 is herein called the *C++ Standard* and ISO/IEC TS 19217:2015 is called the *Concepts TS*.

3 Terms and definitions

[intro.defs]

For the purposes of this document, the terms and definitions given in ISO/IEC 14882:2014, ISO/IEC TS 19217:2015, and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <http://www.iso.org/obp>