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First edition

Information technology — Guidance for the use of database language SQL —

Part 8: Multidimensional arrays

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Phone: +41 22 749 01 11
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Foreword

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This document was prepared by Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 32, *Data management and interchange*.

This first edition of ISO/IEC 19075-8 cancels and replaces ISO/IEC TR 19075-8:2019.

This document is intended to be used in conjunction with the following editions of the parts of the ISO/IEC 9075 series:

— ISO/IEC 9075-1, sixth edition or later,

— ISO/IEC 9075-2, sixth edition or later,

— ISO/IEC 9075-3, sixth edition or later,

— ISO/IEC 9075-4, seventh edition or later,

— ISO/IEC 9075-9, fifth edition or later,

— ISO/IEC 9075-10, fifth edition or later,

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Introduction

This document describes the definition and use of multidimensional arrays in SQL. Multidimensional arrays represent a core underlying structure of manifold science and engineering data. It is generally recognized today, therefore, that arrays have an essential role in Big Data and should become an integral part of the overall data type orchestration in information systems. This document discusses the syntax and semantics of operations on the MD-array data type defined in ISO/IEC 9075-15.

The organization of this document is as follows:

1) Clause 1, "Scope", specifies the scope of this document.
2) Clause 2, "Normative references", identifies standards that are referenced by this document.
3) Clause 3, "Terms and definitions", defines the terms and definitions used in this document.
4) Clause 4, "Multidimensional arrays (MDA) concepts", introduces the concept of Multidimensional Arrays.
5) Clause 5, "SQL/MDA data model", introduces the data model.
6) Clause 6, "SQL/MDA operations", covers the supported operations on MD-arrays.
7) Clause 7, "Remote sensing example", illustrates the supported functionality through realistic examples.

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Information technology — Guidance for the use of database language SQL —

Part 8:
Multidimensional arrays

1 Scope

This document describes the definition and use of multidimensional arrays in SQL. Multidimensional arrays represent a core underlying structure of manifold science and engineering data. It is generally recognized today, therefore, that arrays have an essential role in Big Data and should become an integral part of the overall data type orchestration in information systems. This document discusses the syntax and semantics of operations on the MD-array data type defined in ISO/IEC 9075-15.

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2 Normative references

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.

ISO/IEC 9075-1, *Information technology — Database languages — SQL — Part 1: Framework (SQL/Framework)*

ISO/IEC 9075-2, *Information technology — Database languages — SQL — Part 2: Foundation (SQL/Foundation)*

ISO/IEC 9075-15, *Information technology — Database languages — SQL — Part 15: Multidimensional Arrays (SQL/MDA)*

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3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
coordinate
non-empty ordered list of integers

3.2
cardinality
number of elements in an MD-array

3.3
MD-array
ordered collection of elements of the same type associated with an MD-extent where each element is 1:1 associated with some coordinate within its MD-extent

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Note 1 to entry: A coordinate is within an MD-extent if every coordinate value from the integer list is greater than or equal to the lower limit, and less than or equal to the upper limit of the MD-interval of the MD-axis at the position in the MD-extent as the coordinate value has within the coordinate

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3.4
MD-axis
named MD-interval

3.5
MD-dimension
number of MD-axes in the MD-extent of an MD-array

Note 1 to entry: Also known as “rank” outside of SQL/MDA

3.6
MD-extent
non-empty ordered collection of MD-axes with no duplicate names

3.7
MD-interval
integer interval given by a pair of lower and upper integer limits such that the lower limit is less than or equal to the upper limit; the interval is closed, i.e.,, both limits are contained in it

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4 Multidimensional arrays (MDA) concepts

4.1 Context of multidimensional arrays

The requirements for the material discussed in this document shall be as specified in ISO/IEC 9075-1 and ISO/IEC 9075-15.

4.2 Concept

The phrase "(Multidimensional) array, raster data" is used to refer to arrays generally, in contrast to the MD-array term confined to the realm of SQL/MDA. It is not to be confused with the term "array" in ISO/IEC 9075-2. This document uses the term ARRAY for the original SQL array collection type.

The array concept is a simple and efficient data representation that finds its use in a wide array of fields, business-related as well as scientific and engineering. Many sensors, images, image time-series, simulation processes, statistical models, and so on, produce raw data that can immediately be classified as array data. These data may be naturally arranged along more than one axis: position and time, for example.

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A *multidimensional array* (MDA) is a set of elements ordered in a multidimensional space. The space considered here is discretized (also called rasterized or gridded), that is, only integer coordinates are admitted as positions of the individual array elements. The number of integers needed to refer to a particular position in this space is the array's dimension (sometimes also referred to as its dimensionality).

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An element can be a single value (such as an intensity value in case of greyscale images) or a composite value (such as integer triples for the red, green, and blue components of a true-color image). All elements of an array share the same structure, referred to as the array's element type.

4.3 Why consider support for MDA in SQL?

Large multidimensional arrays in particular represent a prevalent data type across most scientific domains, with examples including 1-D sensor data, 2-D satellite images and microscope scans, 3-D x/y/t image time-series and x/y/z voxel models, as well as 4-D and 5-D climate models.

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Figure 1 — Aerial greyscale image of size 1024x1024 (San Diego)

In array terms, the image in Figure 1, "Aerial greyscale image of size 1024x1024 (San Diego)", is a 2-dimensional array of unsigned 8-bit integer elements positioned at coordinates in $\{0, 1, ..., 1023\}^2$ space.

Arrays rarely occur isolated in practice and are typically ornamented with metadata and embedded in larger overall information structures. Supporting them in narrowly specialized *ad hoc* tools or dedicated array DBMS is thus insufficient when it comes to building modern, complex services and applications. This suggests that integration of array querying into a standardized framework like SQL is a logical next step that will benefit the communities dealing with multidimensional array data in one way or the other.

SQL has had basic support for 1-dimensional arrays since 1999. Instead of attempting to extend the existing 1-dimensional array model to address the needs of multidimensional array manipulation, SQL/MDA addresses those needs with a new feature set integrated into SQL.

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