Annex I
(informative)

Conformance testing for SRF operations

I.1 Overview

This annex provides guidelines that may be useful for developing conformance requirements and conformance tests for implementation of the concepts specified in this document including, but not limited to, the API specified in Clause 11.

I.2 Computational error

The meaning of “error” depends on the context and application domain. Potential sources of error in SRF operations include formulation error, numerical approximation error, round-off error, truncation error and other errors associated with implementing SRF operations. In Annex B, computational error is defined to be the sum of digitization error, and those approximation errors made to simplify the implementation and/or to improve the computational efficiency of the process. Errors of this nature should not be confused with errors arising from modelling the true shape of a spatial object (celestial or abstract) by an approximation of the shape. In this document, an ORM used to approximate the shape of an object is assumed exact. How well an ORM approximates the shape of a celestial object is outside the scope of this document.

The specification of an SRF operation defines the domain and range, as well as providing a functional specification of how each value in the domain is converted into a value in the range. The functional specifications are the mathematical functions in one or more variables given in Clause 10. These functional specifications include a set of rules related to the appropriate ORMs, CSs, and bindings to the CSs.

I.3 SRF operations baseline

Each SRF operation specified in Clause 10 has a theoretically exact specification in terms of mathematical functions. These formulations are specified assuming the use of theoretically exact arithmetic (infinite precision) for developing values of an SRF operation. These exact specifications fall into one of four basic categories:

a) a finite sum of elementary mathematical functions,

b) a finite sum of quadratures,

c) an infinite iterative process, or

d) an infinite power series.

In practice, implementations that use one of these categories require the use of finite precision arithmetic along with termination in a finite number of steps or after a finite number of terms are computed. Some of the formulations may have removable singularities in the domain of a function. When implementing such formulations, care should be taken in the neighbourhood of singularities to use the appropriate numerical approximations or to isolate the singular points with an open set.

I.4 Implementations

This document may be implemented in many ways. Potential implementations include:

a) manual computation without using computers,

b) fixed-purpose hardware, or

c) software executing on general-purpose digital computers ranging from embedded processors to large-scale computer systems.

Given the wide range of possible implementations and the differing requirements of application domains, conformance requirements in this document may be restricted to a sub-set of the domains involved (see Clause 12). (See Annex B for a discussion of computational error, and Clause 14 for specifics on conformance.)

I.5 Fundamental measure of conformance

There are several conformance criteria that are discussed in Clause 14. One fundamental measure is the numerical difference between the individual data points of an exact or reference set of points, and the corresponding data points generated by a particular implementation. The absolute difference between a data point in the reference data set and the corresponding data point obtained from a particular implementation is referred to as a computational error. The computational error may have units of length, may be angular measures or may be dimensionless, depending on the particular SRF operation being evaluated.

When the reference data are generated, a computational digital accuracy at least as accurate as double precision is assumed, as specified in ISO/IEC/IEEE 60559. This means that the size of the mantissa of a floating-point number is 52 bits, which corresponds to about 15,5 decimal digits of precision (see ISO/IEC/IEEE 60559). Particular implementations may not have to meet this requirement on precision, but developers of the system should understand that use of lower precision arithmetic could increase the computational error when dealing with SRF operations.

I.6 Error metrics for SRF operations

An error metric is a function that allows data points developed using the exact formulations of Clause 10 to be numerically compared to corresponding data points generated by an implementation. The value of the error metric represents the computational error. Computational errors as defined in this document are absolute errors. These are positive numbers and may have units of measure associated with them.

Given an exact (or reference) position (x_0, y_0, z_0) in position-space and a computed value (x, y, z) for that position, the error in the computation is given directly in metres by:

$$E = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}$$

where $\Delta x = x - x_0, \Delta y = y - y_0, \Delta z = z - z_0$.

For SRF operations, error metrics are expressed in terms of the coordinate-components of the target SRF. These are obtained from the formulation of E by substituting expressions for $\Delta x, \Delta y, \Delta z$ in terms of the CS coordinate-components of the target SRF.

In the case of a target SRF based on the Euclidean 3D or the Lococentric Euclidean 3D CSs, direct substitution of the (isomorphic) generating functions yields:

$$E = \sqrt{\Delta u^2 + \Delta v^2 + \Delta w^2}$$

where $(\Delta u, \Delta v, \Delta w) = (u, v, w) - (u_0, v_0, w_0)$ is the difference between the exact and computed coordinates.

For a target SRF based on a non-linear CS, and assuming that the error is small, the following approximations for $\Delta x, \Delta y, \Delta z$ apply:

$$\Delta x = \frac{\partial f}{\partial \alpha}\Delta\alpha + \frac{\partial f}{\partial \beta}\Delta\beta + \frac{\partial f}{\partial \gamma}\Delta\gamma$$

