4 Concepts

4.1 Overview

The SRM provides an integrated framework and precise terminology for describing spatial concepts and operations on spatial information. The SRM includes the following features:

a) precise and uniform definitions of commonly used spatial coordinate systems, including those based on map projections,

b) spatial referencing of positions, directions, vector quantities, and orientations for physical and abstract objects,

c) spatial operations and transformations on positions, directions, vector quantities, and orientations, including coordinate conversions and transformations, and calculations of distances and other geometric quantities,

d) an application program interface for performing the defined spatial operations,

e) codes and labels to support the encoding and exchange of spatial data,

f) an extensible framework that supports the registration of additional instances of SRM concepts, and

g) profiles to allow subsets of the SRM to be defined to conform to the specific requirements of an application or an application domain.

This document is based on the following set of foundational and unifying core concepts, which are addressed in greater detail in the remainder of this clause and subsequent clauses:

a) Spatial points are identified by coordinates in a *spatial reference frame* associated with a spatial object of interest, such as the Earth or an engineering model. An *object-space* is the collection of points associated with a spatial object of interest (see 4.2.3).

b) *Position-space* is the Euclidean vector space of dimension $n = 1$, 2 or 3 that serves as a mathematical abstraction of object-space of matching dimension. In both position-space and object-spaces, *orthonormal frames* are defined by the selection of an origin point and a set of mutually perpendicular basis vectors. A *normal embedding* is a length-preserving function that maps positions in position-space to points in an object-space of the same dimension. There are infinitely many possible normal embeddings of an n-dimensional position-space for a given object-space (see 4.2.2).

c) An *abstract coordinate system* assigns a unique coordinate n-tuple defined in a *coordinate-space* to each point in a subset of position-space of dimension n or greater. An abstract coordinate system has a *generating function* that assigns a coordinate in coordinate-space to a corresponding point in position-space (see 4.3.1).

d) A *spatial coordinate system* assigns a unique coordinate in coordinate-space to each point in a region of object-space. A spatial coordinate system assigns a coordinate in coordinate-space to a unique point in object-space using a spatial generating function that is the functional composition of an abstract coordinate system generating function with a normal embedding. Different normal embeddings produce different spatial coordinate systems (see 4.3.2).

e) A *temporal coordinate system* is a Euclidean 1D coordinate system that assigns a one-to-one relationship between temporal coordinate values and instants in time. Temporal coordinate systems are used when spatial coordinate values are time-dependent to associate unique instants in time with events or references (see 4.3.3).

f) *Orientation* is the rotational relationship between a rigid object of interest and a reference. Orientation is specified in terms of the angular displacement, or attitude, of the object's orthonormal frame with respect to an orthonormal reference frame (see 4.4).

g) A *reference datum* is a geometric primitive, such as a point, directed curve, or oriented surface in position-space, whose determining characteristics are bound to a measured or conceptual geometric aspect of a spatial object in an object-space (see 4.5).

h) An *object reference model* is a set of bound reference datums that implicitly defines a unique normal embedding of position-space into object-space. An object reference model is a generalised abstraction of the geodesy notion of a datum (see 4.6).

i) A *spatial reference frame* is a means of specifying a spatial coordinate system for an object-space. A spatial reference frame specification includes (1) an object reference model, (2) a compatible abstract coordinate system, and (3) the binding of object reference model parameters to corresponding abstract coordinate system parameters (if any). The normal embedding implicitly defined by the object reference model is then functionally composed with the abstract coordinate system to produce a spatial coordinate system for the object-space (see 4.7).

j) *Vertical offset surfaces* are introduced to define heights with respect to equipotential or other complex surfaces (see 4.8).

Diagrams that illustrate SRM concepts and their relationships can be found in Annex C.

The relationships among some of these concepts are depicted in Figure 4.1. In this figure, spherical coordinate tuples are defined in a coordinate-space. An abstract spherical coordinate system is then defined by its generating function, which uniquely assigns spherical coordinate tuples to each point in 3D position-space, based on its canonical orthonormal frame. A normal embedding implicitly defined by an object reference model of the Earth is used to map the position-space orthonormal frame to a corresponding orthonormal frame embedded in the Earth's object-space. A spatial coordinate system based on this embedded frame allows points in the Earth's object-space to be located, and various spatial operations to be performed.

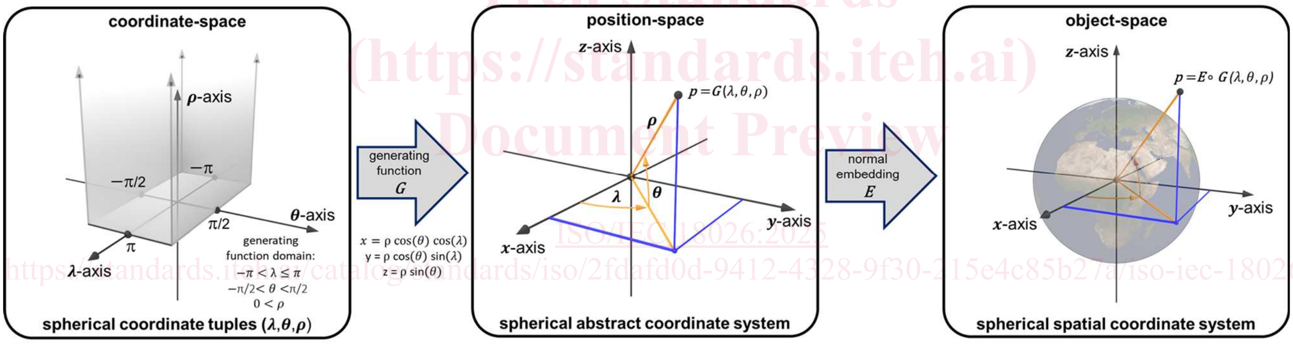

Figure 4.1 — Coordinate-space, position-space, and object-space relationships

The concepts introduced in this subclause are discussed in greater detail in the remainder of this clause. This document takes a functional approach to the definition of these concepts. Basic geometric concepts, including the concepts of point, line, and plane, are assumed. Annex A provides a concise summary of mathematical concepts, including specialized concepts, and notational conventions used in this document.

In this document, the unit of length is the metre and the unit of angular measure is the radian (see ISO 80000-3) unless explicitly identified otherwise. Some angular values are specified in the units of either arc degree or arc second, to support common usage or to prevent loss of precision in data specification.

An application or an exchange format using the data storage structures specified in this document (see 11.5) may use equivalent units of measure, provided those units are identified. For a unit not defined in ISO 80000-3, the conversion factor to metre or radian, as appropriate, shall be explicitly stated. One suitable mechanism for accomplishing the identification of a unit is to use unit and unit scale identifiers as specified in Clause 7 of ISO/IEC 18025.

When interfacing with the methods and/or functions of the SRM (see 4.10), applications shall use the units of metre and radian, as appropriate. All length and angular data shall be converted to the units of metre or radian, as appropriate, before the data is provided as input to an SRM method or function.

When measures of computational accuracy are being determined, such measurements shall be expressed in the units of metre and radian, where applicable.

4.2 Coordinate-space, position-space, and object-space

4.2.1 Coordinate-space

A *coordinate* is an ordered n-tuple $(1 \leq n \leq 3)$. A *coordinate-component* is an individual component of a coordinate n-tuple. A *coordinate-space* specifies a set of coordinate n-tuples that forms a Euclidean vector space (see A.2). The domain of a coordinate system is a replete subset of coordinate space. Such coordinate n-tuples include, but are not restricted to, Cartesian (x, y, z), polar (ρ, θ), cylindrical (ρ, θ, h), and geodetic (λ, φ, h).

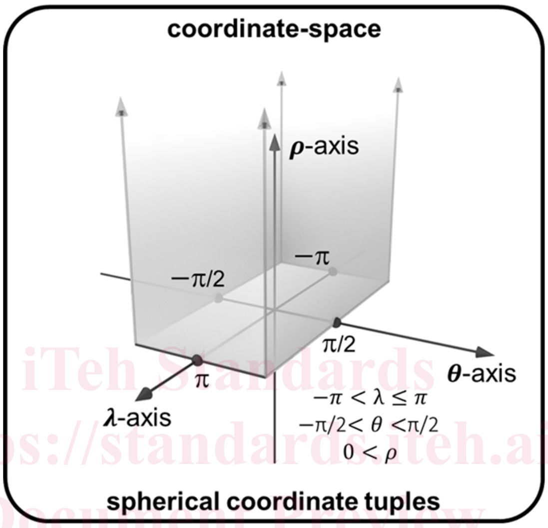

Figure 4.2 — A coordinate-space (for spherical coordinates)

Figure 4.2 illustrates the structure of a coordinate-space for 3D spherical coordinate tuples of the form (λ, θ, ρ). The coordinate-components of these tuples are:

- λ: longitude in radians, such that $-\pi < \lambda \leq \pi$,
- θ: spherical latitude in radians, such that $-{}^{\pi}/_{2} < \theta < {}^{\pi}/_{2}$, and
- ρ: radius in metres, such that $0 < \rho$.

Coordinate-space is further defined in 5.2.1.

4.2.2 Position-space and orthonormal frames

Position-space of dimension m, $(1 \leq n \leq m \leq 3)$, is the Cartesian vector space $\mathbb{R}^m$ (see A.2), which serves as a mathematical abstraction of an object-space. Position-space allows abstract coordinate systems to be applied to object-spaces for many different types of spatial objects of interest.

An ordered set of m mutually perpendicular unit position vectors forms a canonical Cartesian basis for position-space, which allows positions, directions, vector quantities, and distance measurements in position-space to be quantified.

The origin and Cartesian basis vectors together define an *orthonormal frame*. Every point in position-space is uniquely represented by a linear combination of the orthonormal frame's basis vectors represented by a corresponding n-tuple of scalars in the basis order. An orthonormal frame is *right-handed* if the vertices of the triangle formed by its basis unit vectors are in clockwise order when viewed from the origin, as defined in ISO 80000-2.