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Geographic information — Reference model —

Part 1: Fundamentals

Information géographique — Modèle de référence —

Partie 1: Principes de base

Reference number
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Foreword

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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 ISO documents 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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 211, *Geographic information/Geomatics*.

This first edition of ISO 19101-1, together with ISO/TS 19101-2:2008, cancels and replaces ISO 19101:2002.

ISO 19101 consists of the following parts, under the general title *Geographic information — Reference model*:

— *Part 1: Fundamentals*

— *Part 2: Imagery* [Technical Specification]

Introduction

Beyond the needs within traditional applications of digital geographic information, users of information technology recognize that indexing by location is fundamental in the organization and the use of digital data. Nowadays, digital data from multiple sources of a wide variety are being referenced to locations and used in various applications. Such data are now extensively distributed and shared over the Web. In fact, the Web is an important source of knowledge in which geographic information plays a significant role. Standardization in the field of geographic information is therefore imperative to support and simplify the sharing and usage of geographic information of different sources, i.e. interoperability.

Standardization in geographic information is a complex task that addresses multiple aspects encompassing the definition of interoperability of geographic information, fundamental data types such as for spatial and temporal information, modelling rules, the semantics of real world phenomena, metadata, services, etc. As such, a reference model is required in order to achieve this task in an integrated and consistent manner. A reference model in geographic information consists of a comprehensive view providing an abstract description of the elements that might compose the field of geographic information and their interrelations. One of the primary goals of this reference model is to define and describe interoperability of geographic information, addressing system, syntactic, structural, and semantic levels. The definition of interoperability of geographic information will then serve as the underpinning for standardization in geographic information. It contributes to

— increase the understanding and usage of geographic information,

— increase the availability, access, integration, and sharing of geographic information,

— promote the efficient, effective, and economic use of digital geographic information and associated hardware and software systems, and

— enable a unified approach to addressing global ecological and humanitarian problems.

This part of ISO 19101 defines the ISO reference model dealing with geographic information. This reference model provides a guide to structuring geographic information standards in a way that it will enable the universal usage of digital geographic information. It sets out the fundamentals for standardization in geographic information including description, management, and services, and how they are interrelated to support interoperability within the geographic information realm and beyond to ensure interoperability with other information communities. As such, this part of ISO 19101 develops a vision for the standardization in geographic information from which it would be possible to integrate geographic information with other types of information and conversely.

The description of the reference model is supported by a conceptual framework. The conceptual framework is a mechanism to structure the scope of the standardization activity in geographic information according to the interoperability description. It identifies the various facets of standardization and the relationships that exist between them.

This reference model settles the role of semantics, how the new technologies such as the Web and many emerging ways of accessing it, and how the Semantic Web can support interoperability in the field of geographic information. It also provides an umbrella under which additional specific reference models on particular facets of geographic information standardization would be required.

The reference model is organized in five clauses. Clause 5 describes interoperability in the context of geographic information from a communication and an e-government perspective. Clause 6 identifies the foundations of the reference model and sets the scope (requirements) for the ISO geographic information standardization activities. Clause 7 identifies the requirement for the abstraction of the real world. The reference model for ISO standardization in geographic information is specified in Clause 8 along with its specific requirements. Finally, profiles related to ISO geographic information standards are introduced in the Clause 9.

This part of ISO 19101 is the first part of the reference model. Additional parts can be developed to address concerns, elements, and structures in distinct areas. As such, part 2 of the reference model addresses specific aspects on imagery.

To achieve these goals, standardization of geographic information in the ISO geographic information standards is based on the integration of the concepts of geographic information with those of information technology. The development of standards for geographic information has to consider the adoption or adaptation of generic information technology standards whenever possible. It is only when this cannot be done that the development of geographic information standards becomes required.

This part of ISO 19101 identifies a generic approach to structuring the ISO geographic information standards. This reference model uses concepts from the Open Distributed Processing – Reference Model (RM ODP) described in ISO/IEC 10746-1[17] and other relevant International Standards and Technical Reports. This part of ISO 19101 does not prescribe any specific products or techniques for implementing geographic information systems.

This part of ISO 19101 is intended to be used by information system analysts, program planners, and developers of geographic information standards that are related to ISO geographic information standards, as well as others in order to understand the basic principles of this series of standards and the overall requirements for standardization of geographic information.

This edition of the reference model differs from its previous edition by having a specific focus on the semantic aspects related to interoperability of geographic information by the way of ontologies and knowledge. As such, the definition of interoperability has been revisited in the context of communication. Three foundations for interoperability of geographic information are identified. Based on these foundations and the usual four levels of abstraction, a new conceptual framework is introduced to support the organization of the reference model. The architectural aspect of the previous reference model has been removed in this reference model and will be addressed more specifically in a revision of ISO 19119:2005. This version of the reference model has no backward compatibility impact on the ISO geographic information suite of standards.

Geographic information — Reference model —

Part 1: Fundamentals

1 Scope

This part of ISO 19101 defines the reference model for standardization in the field of geographic information. This reference model describes the notion of interoperability and sets forth the fundamentals by which this standardization takes place.

Although structured in the context of information technology and information technology standards, this part of ISO 19101 is independent of any application development method or technology implementation approach.

2 Conformance

General conformance and testing requirements for the ISO geographic information standards are described in ISO 19105.

Any standards and profiles claiming conformance to this part of ISO 19101 shall satisfy all the requirements described in the abstract test suites in Annex A.

Additional specific conformance requirements are described in individual ISO geographic information standards.

3 Normative references

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

Not applicable.

4 Terms, definitions, and abbreviated terms

4.1 Terms and definitions

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

4.1.1
application
manipulation and processing of data in support of user requirements

4.1.2
application schema
conceptual schema (4.1.6) for data required by one or more *applications* (4.1.1)

4.1.3
base standard
ISO *geographic information* (4.1.18) standard or other information technology standard that is used as a source from which a *profile* (4.1.27) might be constructed

[SOURCE: ISO 19106:2004, 4.2]

4.1.4
conceptual formalism
set of modelling concepts used to describe a *conceptual model* (4.1.5)

EXAMPLE 1 UML meta model.

EXAMPLE 2 EXPRESS[21] meta model.

Note 1 to entry: One conceptual formalism can be expressed in several *conceptual schema languages* (4.1.7).

4.1.5
conceptual model
model that defines concepts of a *universe of discourse* (4.1.38)

4.1.6
conceptual schema
formal description of a *conceptual model* (4.1.5)

4.1.7
conceptual schema language
formal language based on a *conceptual formalism* (4.1.4) for the purpose of representing *conceptual schemas* (4.1.6)

EXAMPLE 1 UML.

EXAMPLE 2 EXPRESS.

EXAMPLE 3 IDEF1X.

Note 1 to entry: A conceptual schema language can be lexical or graphical. Several conceptual schema languages can be based on the same conceptual formalism.

4.1.8
coverage
feature (4.1.11) that acts as a function to return values from its range for any direct position within its spatial, temporal, or spatiotemporal domain

EXAMPLE 1 *Raster* (4.1.30) image.

EXAMPLE 2 Polygon overlay.

EXAMPLE 3 Digital elevation matrix.

Note 1 to entry: In other words, a coverage is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type.

[SOURCE: ISO 19123:2005, 4.1.7]

4.1.9
dataset
identifiable collection of data

[SOURCE: ISO 19115-1:2014, 4.3]

4.1.10
e-government
digital interaction between a government and citizens, government and businesses, and between government agencies

4.1.11
feature
abstraction of real world phenomena

Note 1 to entry: A feature can occur as a type or an instance. Feature type or feature instance will be used when only one is meant.

4.1.12
feature attribute
characteristic of a *feature* (4.1.11)

EXAMPLE 1 A feature attribute named “colour” can have an attribute value “green” which belongs to the data type “text”.

EXAMPLE 2 A feature attribute named “length” can have an attribute value “82,4” which belongs to the data type “real”.

Note 1 to entry: A feature attribute has a name, a data type, and a value domain associated to it. A feature attribute for a *feature instance* (4.1.14) also has an attribute value taken from the value domain.

Note 2 to entry: In a *feature catalogue* (4.1.13), a feature attribute can include a value domain but does not specify attribute values for feature instances.

Note 3 to entry: In UML, attributes, associations, and operations are representation types and are not fundamental to the type of a characteristic nor to the type of feature. All three are equally capable of representing the same characteristic of a feature. Every implementation of a characteristic is allowed to use the representation type that is most appropriate and can use several different representations for a single characteristic if required. Feature associations and *feature operations* (4.1.15), therefore, are different types of feature attribute, the distinction between them being based on storage and access mechanisms rather than semantics.

4.1.13
feature catalogue
catalogue containing definitions and descriptions of the *feature types* (4.1.16), *feature attributes* (4.1.12), and feature relationships occurring in one or more sets of geographic data, together with any *feature operations* (4.1.15) that can be applied

4.1.14
feature instance
individual of a given *feature type* (4.1.16) having specified *feature attribute* (4.1.12) values

4.1.15
feature operation
operation that every instance of a *feature type* (4.1.16) can perform

EXAMPLE A feature operation upon a “dam” is to raise the dam. The results of this operation are to raise the height of the “dam” and the level of water in a “reservoir”.

Note 1 to entry: Feature operations provide a basis for feature type definition.

[SOURCE: ISO 19110:2005, 4.5]

4.1.16
feature type
class of *features* (4.1.11) having common characteristics

[SOURCE: ISO 19156:2011, 4.7]

4.1.17
functional standard
existing *geographic information* (4.1.18) standard, in active use by an international community of data producers and data users

EXAMPLE 1 GDF[22].

EXAMPLE 2 S-57[15].

EXAMPLE 3 DIGEST[6].

4.1.18
geographic information
information concerning phenomena implicitly or explicitly associated with a location relative to the Earth

4.1.19
geographic information service
service (4.1.36) that transforms, manages, or presents *geographic information* (4.1.18) to users

4.1.20
geographic information system
information system (4.1.23) dealing with information concerning phenomena associated with location relative to the Earth

4.1.21
graphical language
language whose syntax is expressed in terms of graphical symbols

4.1.22
grid
network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in an algorithmic way

Note 1 to entry: The curves partition a space into grid cells.

[SOURCE: ISO 19123:2005, 4.1.23]

4.1.23
information system
information processing system, together with associated organizational resources such as human, technical, and financial resources, that provides and distributes information

[SOURCE: ISO/IEC 2382-1:1993, 01.01.22]

4.1.24
lexical language
language whose syntax is expressed in terms of symbols defined as character strings

4.1.25
module
predefined set of elements in a base standard that can be used to construct a profile

[SOURCE: ISO/TR 19120:2001, 3.3]

4.1.26
ontology
formal representation of phenomena of a *universe of discourse* (4.1.38) with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships

4.1.27
profile
set of one or more *base standards* (4.1.3) or subsets of base standards, and, where applicable, the identification of chosen clauses, classes, options, and parameters of those base standards, that are necessary for accomplishing a particular function

[SOURCE: ISO 19106:2004, 4.5]

4.1.28
quality
degree to which a set of inherent characteristics fulfils requirements

Note 1 to entry: The term "quality" can be used with adjectives such as poor, good, or excellent.

Note 2 to entry: "Inherent", as opposed to "assigned", means existing in something, especially as a permanent characteristic.

[SOURCE: ISO 9000:2005, 3.1.1]

4.1.29
quality schema
conceptual schema (4.1.6) defining aspects of *quality* (4.1.28) for geographic data

4.1.30
raster
usually rectangular pattern of parallel scanning lines forming or corresponding to the display on a cathode ray tube

Note 1 to entry: A raster is a type of *grid* (4.1.22).

[SOURCE: ISO 19123:2005, 4.1.30]

4.1.31
reference model
framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment

Note 1 to entry: A reference model is based on a small number of unifying concepts and can be used as a basis for education and explaining standards to a non-specialist.

[SOURCE: ISO 14721:2012, 1.7.2, modified]

4.1.32
register
set of files containing identifiers assigned to items with descriptions of the associated items

[SOURCE: ISO 19135:2005, 4.1.9]

4.1.33
registry
information system (4.1.23) on which a *register* (4.1.32) is maintained

[SOURCE: ISO 19135:2005, 4.1.13]

4.1.34
schema
formal description of a model

4.1.35
Semantic Web
Web (4.1.40) of data with meaning

Note 1 to entry: The association of meaning allows data and information to be understood and processed by automated tools as well as by people.

4.1.36
service
distinct part of the functionality that is provided by an entity through interfaces

[SOURCE: ISO 19119:2005, 4.1]

4.1.37
tessellation
partitioning of a space into a set of conterminous subspaces having the same dimension as the space being partitioned

Note 1 to entry: A tessellation composed of congruent regular polygons or polyhedra is a regular tessellation. One composed of regular, but non-congruent, polygons or polyhedra is a semi-regular tessellation. Otherwise, the tessellation is irregular.

[SOURCE: ISO 19123:2005, 4.1.39]

4.1.38
universe of discourse
view of the real or hypothetical world that includes everything of interest

4.1.39
vector
quantity having direction as well as magnitude

Note 1 to entry: A directed line segment represents a vector if the length and direction of the line segment are equal to the magnitude and direction of the vector. The term vector data refers to data that represents the spatial configuration of *features* (4.1.11) as a set of directed line segments.

[SOURCE: ISO 19123:2005, 4.1.43]

4.1.40
World Wide Web
Web
universe of network-accessible information and *services* (4.1.36)

4.1.41
Web service
service (4.1.36) that is made available through the *Web* (4.1.40)

Note 1 to entry: A Web service usually includes some combination of programming and data. It can also include human resources.

4.2 Abbreviated terms

COM	Component Object Model
CORBA	Common Object Request Broker Architecture
CSMF	Conceptual Schema Modelling Facility
DL	Description Language
DXF	Drawing eXchange Format

ebXML RIM	Electronic Business XML Registry Information Model
ebXML RS	Electronic Business XML Registry Services
EIF	European Interoperability Framework
FTP	File Transfer Protocol
GeoRSS	Geo Really Simple Syndication
GFM	General Feature Model
GIS	Geographic Information System
GML	Geography Markup Language
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
ICT	Information and Communication Technology
IDEF1X	Integration DEFinition for Data Modelling
IDL	Interface Definition Language
IT	Information Technology
JDBC	Java Database Connectivity
KML	Keyhole Markup Language
MS	Microsoft Corporation
OCL	Object Constraint Language
ODBC	Open Database Connectivity
ODL	Object Definition Language
ODMG	Object Data Management Group
ODP	Open Distributed Processing
OMG	Object Management Group
OWL	Web Ontology Language
RDF	Resource Description Framework
RM-ODP	Reference Model – Open Distributed Processing
RPC	Remote Procedure Call
SDAI	Standard Data Access Interface
SDI	Spatial Data Infrastructure
SQL	Structured Query Language
TCP/IP	Transmission Control Protocol/Internet Protocol

UML	Unified Modelling Language
URI	Universal Resource Identifier
W3C SWEO	World Wide Web Consortium Semantic Web Education and Outreach
XML	eXtensible Markup Language

5 Interoperability

5.1 Interoperability of geographic information

5.1.1 Conceptual framework

Interoperability has been widely defined in various contexts related to information technology. The most fundamental definitions come from the Institute of Electrical and Electronics Engineers and ISO/IEC 2382-1:1993.

— The ability of two or more systems or components to exchange information and to use the information that has been exchanged[10].

— The capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units[16].

In these definitions, the capability to use the information exchanged and the communication capability between units are meaningful elements. As such, this part of ISO 19101 compares interoperability of geographic information to an interpersonal communication process and establishes a framework for interoperability of geographic information, which is detailed hereafter. Interoperability of geographic information in the suite of ISO geographic information standards shall be founded on this framework.

Interoperability is presented here within the wider scope of human communication and cognition since people usually end up understanding each other when interacting using different representations of observable phenomena. Typically, a human communication process is about the transmission of details on something that one has in mind to another. It comprises the following parts:

— a human source;

— a human destination;

— physical signals;

— a communication channel;

— a source of noise;

— a feedback mechanism.

In a human communication process, different features are involved especially at the source and destination cognitive models and at the different physical signals constituting the message transmitted between the source and its destination.

Similarly to human communication, interoperability is a process by which independent systems manipulate, exchange, and integrate information that are received from others automatically. Accordingly, the conceptual framework of interoperability of geographic information is presented hereafter.

Interoperability of geographic information is depicted as a communication process that occurs between two agents, a user agent and a provider agent, interacting together about geographic information. Consider that the user agent is interested in getting information about geographic features in a specific area, say points of interest in Paris. Then, the user agent sends a query to the provider agent through the communication channel (e.g. the Internet) using its own concepts and vocabulary. Once the message reaches its destination, the provider agent interprets the request. This means that the provider agent identifies concepts it knows that correspond to the request and for which it has information, and uses them to answer the request (e.g. Eiffel Tower, Champ de Mars, Paris, 48°51’29” Latitude, 2°17’40” Longitude). Then, the provider agent assembles the information in a response that is sent back to the user agent. In turn, at the time when the user agent receives the response from the provider agent, it interprets and assesses it according to its initial request. Interoperability happens in this scenario between the two agents only if the answer of the provider agent satisfies the user agent query.

Figure 1 illustrates the interaction between a user agent and a provider agent in the conceptual framework for the interoperability of geographic information. First, it considers the reality (R) as it is at a given time and about which the user agent is interested to have information.

Second, the user agent model of the reality (R′) results from a set of observed signals and the frame of reference that is used to build it, i.e. the set of rules and knowledge used to abstract phenomena. The user agent model is made of properties considered meaningful that are organized or structured into concepts. A concept is an abstract, generalized, and simplified representation of similar real world phenomena. A concept is entirely fictional, i.e. it does not exist in reality.

Because concepts are purely abstractions, the user agent cannot communicate concepts directly to the provider agent. Therefore, the user agent’s concepts shall be transformed into physical representations, which then can be transmitted through the communication channel. In communication, this refers to the encoding operation. Essentially, this operation represents only the user agent concepts’ properties required to describe the concepts in a specific situation. The concepts’ properties are transformed into signals (e.g. words, abbreviations, punctuations, images, sounds, etc.) and ordered following specific rules, i.e. a grammar, to shape the representation of user agent’s concepts (R″) to constitute the message. This becomes the data transmitted by the user agent to interoperate with the provider agent. Once released on the communication channel, the message representing the user agent’s query, “What is interesting to see in Paris?”, is freed from the user agent’s intended meaning.

When the message reaches its destination, the provider agent begins the decoding operation, which consists of the recognition of and the assignment of an appropriate meaning to the message’s physical representations. Although under perfect conditions representations of concepts induce user agent’s isomorphic concepts to the provider agent, typically, representations of concepts induce concepts to the provider agent (R‴) that are of similar meaning to user agent’s concepts. These concepts are then used to answer the user agent’s query.

Based on these concepts, the provider agent begins the retrieval of information. Similarly to R′, the retrieved information (either concepts or instances of them) cannot be communicated directly since it consists of features. Consequently, it shall be encoded into physical representations, arranged in a message (R‴′) to be placed as a reply (e.g. an XML encoding of Eiffel Tower, Champ de Mars, Paris, 48°51’29” Latitude, 2°17’40” Longitude) on the communication channel towards the user agent. Once again here when placed on the communication channel, the physical representations are freed of their provider agent’s meaning.

In turn, at the time the response message is received, the user agent initiates the decoding operation to recognize the components of the message and to give them a meaning and, after, assesses if that meaning infers the concepts in R′. If it is the case, the user and the provider agents interoperate successfully.

This conceptual framework describes interoperability of geographic information from an interpersonal communication perspective between two agents. Interoperability of geographic information consists of a bi-directional process that includes feedback in both directions to ensure that messages get to their destination and are understood properly. Each agent uses its own knowledge and vocabulary to express and interpret features. As long as the two agents have a common background and a common set of symbols, they regularly end up understanding each other. This conceptual framework agrees with the IEEE and ISO/IEC 2382-1:1993 definitions of interoperability.

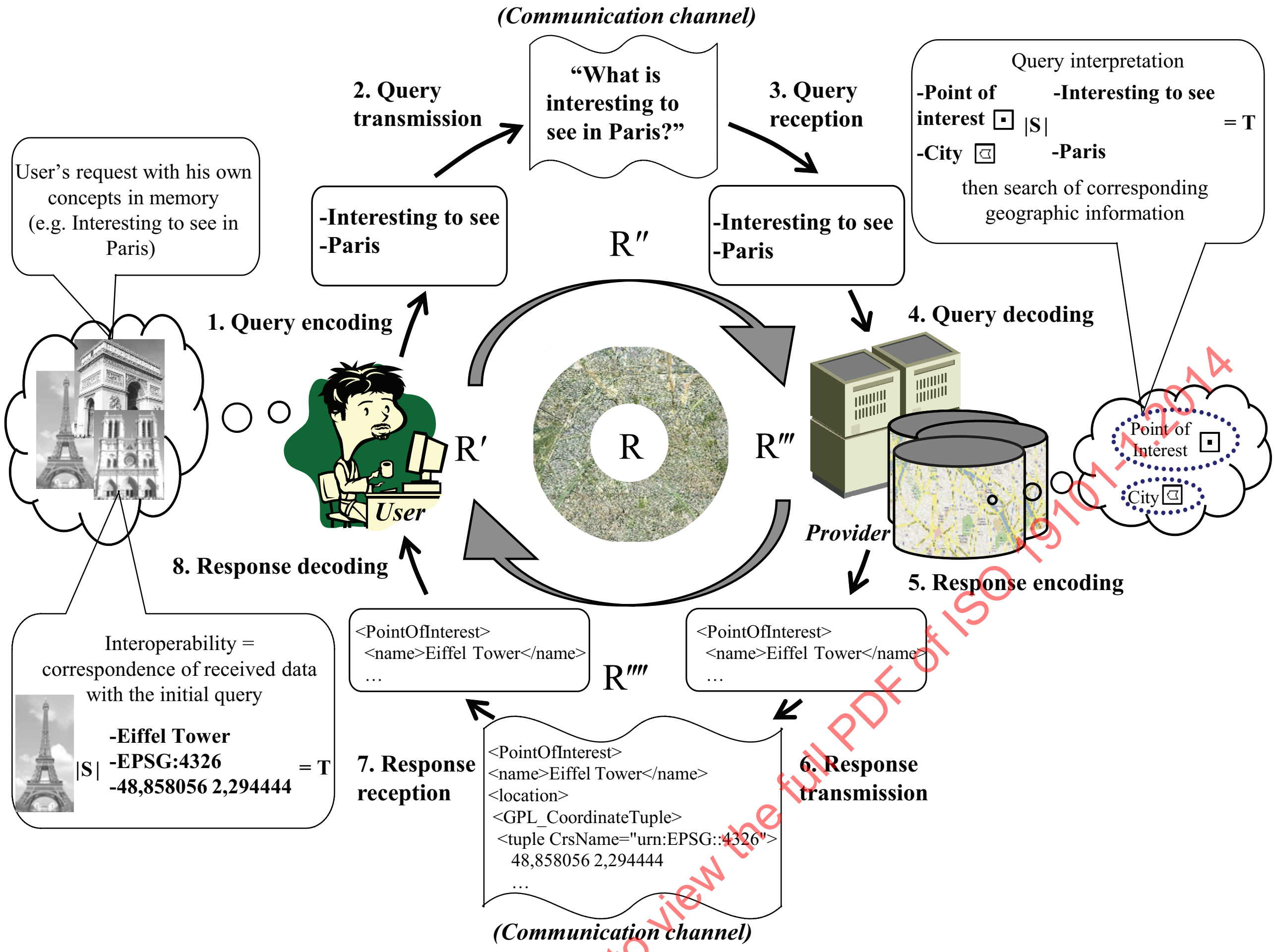

Figure 1 — Conceptual framework for the interoperability of geographic information (adapted from References [3] and [4])

5.1.2 Heterogeneity in geographic information

5.1.2.1 General

Previously decomposed into six layers[2] (see Annex B), interoperability of geographic information aims at establishing an efficient communication between systems and applications handling geographic information and users. It is recognized that systems, applications, and users can be different, and it is essential to overcome the heterogeneity that exists between them to achieve interoperability. Heterogeneity is classified in four different types:

— system heterogeneity;

— syntactic heterogeneity;

— structural heterogeneity;

— semantic heterogeneity.

5.1.2.2 System heterogeneity

Geographic information resides on different and independent systems. The difference between hardware, operating systems, and communication systems are examples of heterogeneity between systems. Therefore, it becomes essential to set interconnections between systems. At this level, communication networks and protocols such as Ethernet, TCP/IP RPC, FTP, HTTP, etc. allow the connection of systems with various operating systems to share data and resources.

Moreover, system interconnection allows various database management systems to share data between them through database connectivity (e.g. ODBC or JDBC) and languages such as SQL.

Although system heterogeneity issues are significant for interoperability of geographic information, ISO geographic information standards do not deal with such issues specifically.

5.1.2.3 Syntactic heterogeneity

Syntactic heterogeneity concerns the physical representation of the data. Syntax defines the symbols and the grammar that are used together to convey data within a message from a sender to a receiver. Syntactic heterogeneity is concerned with the appearance of the message but not in its content. Syntactic heterogeneity appears when an application communicates in a different encoding format than another application, for example, an application sending and receiving data in Shapefile format[7] compared to another sending and receiving in DXF format[1].

Syntactic heterogeneity also appears between the various data structures used by applications to depict geographic information. Geographic information could be depicted either in vector or in tessellation form (e.g. raster form). A vector form uses geometric constructs such as point, line, surface, solid, etc. whereas the raster form consists in a regular mosaic of data elements that are either point or surface (i.e. pixel) elements.

5.1.2.4 Structural heterogeneity

Also called schematic heterogeneity, structural heterogeneity is concerned with the differences related to conceptual modelling of geographic features. Geographic features described by classes, attributes, and relationships can be abstracted differently from one application to another, showing several structural conflicts related to the concept or class definition, concept's properties, geometries, and temporalities. For example, a street can be described either by a class "Street" or by an attribute value street within a class "Road" or a subclass of the class "Road".

5.1.2.5 Semantic heterogeneity

Semantic heterogeneity refers to the difference of meaning between concepts and data used to represent the reality, because of the various perspectives (or contexts) from which real world phenomena were abstracted. For example, the manner two individuals perceive a bridge might lead to different concepts: a road infrastructure, an obstacle for marine navigation, a point of interest, and so on. It is essential to consider semantics of data to achieve the interoperability of geographic information.

5.2 Interoperability of geographic information in e-government

E-government consists of governance, information and communication technology (ICT), business process re-engineering, and citizens at all levels of government (city, state/province, national, and international). Annex C introduces elements of interoperability of geographic information in e-government.

6 Interoperability foundations and scope for the reference model

6.1 Foundations

6.1.1 General

The ISO geographic information standards establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. It is an underpinning for the interoperability in the area of geographic information, which aims to support the development of SDI (see Annex D).

As such, the ISO geographic information standards cover topics that include, but are not limited to, the definition, the description, the management, the discovery, the access, and the processing of geographic information. They specify methods, tools, and services for management of geographic information, including the definition, acquisition, analysis, access, presentation, and transfer of such data in digital/electronic form between different users, systems, and locations. Standardization of geographic information can best be served by a set of standards that integrates a detailed description of the concepts of geographic information with the concepts of information technology.

Based on the conceptual framework for the interoperability of geographic information (5.1), this part of ISO 19101 recognizes the following three major foundations:

a) the semantic foundation;

b) the syntactic foundation;

c) the service foundation.

6.1.2 Semantic foundation

The semantic foundation deals essentially with the meaning and the structure of concepts definition. It is concerned with the manner geographic phenomena are abstracted and modelled into concepts including their thematic, spatial, and temporal characteristics and their documentation either through feature catalogues, dictionaries, or registers. Consequently, it is also concerned with the definition of common concepts of geographic information such as geometry, topology, temporality, spatial referencing (either directly through coordinates, or more indirectly by use of, for instance, area codes like postal or zip codes, addresses, etc.), etc. supporting the abstraction of geographic phenomena. Additionally, information that provides context about geographic data (e.g. quality, metadata) is addressed as part of the semantic foundation. The semantic foundation provides knowledge about geographic information data to enable reasoning.

The semantic foundation addresses the information viewpoint as presented in Reference Model – Open Distributed Processing (RM-ODP)[17] (see Annex D).

Since the development of information content is an important issue for the interoperability of geographic information, the semantic foundation subsumes the development of top-level ontologies which allow ontology mapping between specific domains.

6.1.3 Syntactic foundation

The syntactic foundation is concerned with languages used between systems for communication. It relates to encoding of information through transfer formats and to the visual representation of geographic information based on cartography. It addresses both the encoding of the data itself and the encoding of its semantics, i.e. ontology [e.g. Web Ontology Language (OWL)]. The syntactic foundation is also concerned with the structure by which geographic information is represented. This includes at least the following data structures: vector, grid (including the raster form), coverage, and data structures for linear referencing.

The syntactic foundation relates to the information viewpoint as presented in RM-ODP[17] since it addresses the manner in which information is encoded in the form of data. It is the information viewpoint that provides the semantics to the encoded data. The syntactic foundation relates also to the computational viewpoint of RM-ODP as it encodes the geographic information that is passed through the interfaces between processing units and services. It makes a bridge between the semantic and the service foundations.

6.1.4 Service foundation

Services are related to capabilities that systems or middlewares provide for manipulating, transforming, managing, or presenting geographic information. The service foundation is concerned with the manner a system is invoked remotely, i.e. the interface, to process a specific task. Interfaces are boundaries across which services are invoked and across which data are passed. The service foundation includes the task invocation definition with its set of parameters and return values. It is also concerned with Web services, services based on location, and ubiquitous public access of geographic information.

The service foundation addresses the computational viewpoint as presented in RM-ODP[17]. This foundation is concerned with the cooperation, contract, and interface definition of processing units and services that take part in a geographic information interoperable environment.

6.2 Scope in the ISO geographic information standards

This family of ISO geographic information standards shall define and formalize, but shall not be limited to

— basic concepts, rules, and constructs, and their semantics for the capture, description, and representation of geographic information,

— methods to document the semantics of geographic information,

— elements to describe the contextual information (e.g. metadata),

— domain ontologies,

— geographic data structures (e.g. vector, grid, coverage, etc.),

— observation, measurement, and capture of geographic data,

— protocols and encoding languages required for system intercommunications (e.g. XML encodings),

— geographic information service components and their behaviour for data processing purposes over the Web,

— OWL ontologies to cast ISO/TC 211 International Standards to benefit from and support the Semantic Web, and

— top-level ontologies.

7 Abstraction of the real world

7.1 General

Clause 7 refers to the requirements about the abstraction of the real world in ISO geographic information standards. The concepts that underlie the abstraction of real world phenomena in the ISO geographic information standards are described in Annex E.

7.2 Conceptual formalism

The applicable conceptual formalism for the ISO geographic information standards shall be object-oriented modelling.

7.3 Ontological languages

7.3.1 Graphical language

The ISO geographic information standards shall use first and foremost UML class and package diagrams[39] with OCL[38] as the ontological language for specification of the normative parts of the ISO geographic information standards. UML models create a corpus of knowledge enabling syntactic and semantic interoperability, while supporting multiple interchange formats and multiple service implementations. ISO/TS 19103[33] shall set the specific requirements for the use of UML and OCL languages to structure geographic information and specify the behaviour of geographic information services.

7.3.2 Lexical language

Complementary ontologies in OWL[43] shall be described for concepts defined through ISO geographic information UML diagrams to support interoperability across disciplines through the Semantic Web. ISO 19150-2[31] shall define the rules to convert ISO geographic information UML diagrams and application schemas into OWL.

UML models and OWL ontologies shall co-exist within the ISO geographic information resources and complement each other in terms of semantics.

8 The ISO geographic information reference model

8.1 General

The reference model provides a high-level description of those aspects of geographic information addressed by ISO geographic information standards and describes how they are related together to provide a common basis for communication. Figure 2 shows a high-level diagram of the domain of geographic information. This diagram contains:

— The *data set*, which includes:

1) Features, including feature attributes, feature relationships, and feature operations (defined mathematical operations for computing information about features).

2) Spatial objects that can describe the spatial aspects of features, or are complex data structures that associate values of attributes to individual positions within a defined space. There are two general approaches to model the spatial aspects of geographic information:

   — to perceive the space as occupied by features, which are described by using vector data;

   — to imagine the variation of values of interest over the space as some distribution function (i.e. coverage).

3) Descriptions of the position of spatial objects in space and time, using units of measure provided by reference systems.

— The *application schema*:

The *application schema* provides a description of the features of the data set. The application schema also identifies the spatial object types and reference systems required to provide a complete description of geographic information in the data set. Data quality elements and data quality overview elements are also included in the application schema.

— The *metadata dataset*:

The *metadata dataset* allows users to search for, evaluate, compare, and order geographic data. It describes the administration, organization, contents, and quality of geographic information in data sets. It can contain or reference the application schema for the geographic data set. It can contain or reference the feature catalogue that contains the definitions of concepts used in the application schema.

— *Geographic information services*:

Implemented as software programs, *geographic information services* operate on geographic information contained in data sets. These services reference information in the metadata datasets in order to correctly perform retrieval operations as well as manipulation operations such as transformation and interpolation.

Services access data in a networked environment in which datasets are stored in distributed database management systems. Within datasets, features can be associated with a set of values that is derived from a distribution function in order to provide information about areas.

Non-geographic features are also of interest in ISO geographic information standards. Such features can be included in the application schema with no spatial characteristics.

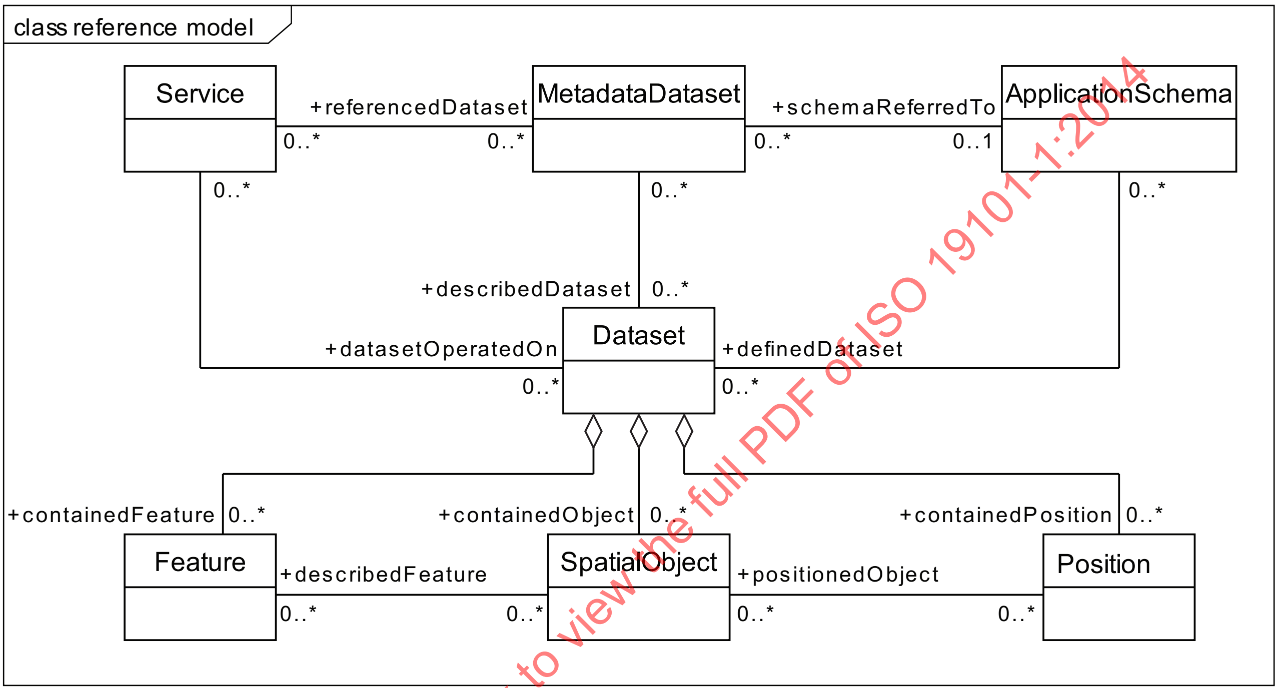

Figure 2 — High-level view of the domain of geographic information

Clause 8 describes the reference model by identifying the various aspects required for standardization in the domain of geographic information as depicted in Figure 2. To support this description, a conceptual framework is introduced in 8.2. Then, the reference model is detailed in 8.3, 8.4, 8.5, and 8.6 according to the conceptual framework. The semantic and structural aspects are described in 8.3. The syntactical aspects are addressed in 8.4. The aspects of services are described in 8.5. The aspects related to procedural standards are addressed in 8.6. Finally, 8.7 provides a more detailed description that is intended for persons who require an in-depth understanding of the ISO geographic information standards and its relationship to the domain of geographic information.

Additionally, Annex F lists the standards covered by the ISO geographic information standards.

Some aspects are not part of the scope of ISO geographic information standards but are shown in italic hereafter to provide additional context about their purpose in the context of ISO geographic information standards.

8.2 Reference model conceptual framework

The purpose of a reference model is to provide a high-level or generalized view and description of those aspects of geographic information that the ISO geographic information standards address. This reference model identifies the components involved in the ISO geographic information standards and describes how they relate together to provide a common basis for communication. However, as science and technology are evolving, it is impossible to identify and describe all aspects that can emerge in the future and would impact standardization activities in geographic information.

To support the description of the reference model, 8.2 introduces a conceptual framework based on the foundations defined in 6.1, i.e. the semantic foundation, the syntactic foundation, and the services foundation, with the addition of procedural standards. Foundations and procedural standards can be described at different levels and this part of ISO 19101 adopts a four-level decomposition, similarly to CSMF (see Annex G):

— meta-meta level;

— meta level;

— application level;

— instance level.

The meta-meta level covers the more general aspects of the ISO geographic information standards including this part of ISO 19101 and, as such, relates to the enterprise viewpoint of RM-ODP[17]. It is also concerned with profiles and functional standards, which consider the technique of profiling. Profiling consists of putting together "packages/subsets" of the total set of standards to fit individual application areas or users. This supports rapid implementation and penetration in the user environments due to the comprehensiveness of the total set of standards. Equally important is the task of "absorbing" existing de facto standards from the commercial sector and harmonizing them with profiles of the emerging International Standards.

The meta level covers aspects of the ISO geographic information standards required for the development of applications. It includes rules-based standards as well as standards defining elements such as data types, data structures, languages for encoding geographic information, and so on.

The application level covers aspects of the ISO geographic information standards addressing areas that can be directly implementable. This includes application schemas for metadata, and ontologies addressing specific domains and applications.

The instance level covers the data, encoded data, and services or application processing data. Although it is included in the reference model conceptual framework for completeness, this level is not part of the scope of this part of ISO 19101.

The integration of these four levels with the concepts described in 6.1, with the inclusion of procedural standards, leads to the definition of the reference model conceptual framework shown in Table 1.

Table 1 — Reference model conceptual framework for the ISO geographic information standards

Reference model conceptual framework				
Level\foundation	**Interoperability**			**Procedural standards**
	Semantic foundation	**Syntactic foundation**	**Service foundation**	
Meta-meta	Meta-meta:Semantic	Meta-meta:Syntactic	Meta-meta:Service	Meta-meta:Procedural
Meta	Meta:Semantic	Meta:Syntactic	Meta:Service	Meta:Procedural
Application	Application:Semantic	Application:Syntactic	Application:Service	Application:Procedural
Instance[a]	*Instance:Semantic*	*Instance:Syntactic*	*Instance:Service*	*Instance:Procedural*

[a] The instance level is included in the reference model conceptual framework for completeness but is not part of the scope of this part of ISO 19101. This applies further on to 8.3.4, 8.4.4, 8.5.4, and 8.6.4.

This framework is a mechanism to structure the description of the reference model including the various facets and levels of interoperability that happen in geographic information. It provides a generalized view that enables the identification of the very nature of the contribution of each standard to the family of ISO geographic information standards.

8.3 Reference model — Semantic foundation

8.3.1 Meta-meta:Semantic

Meta-meta:Semantic shall consist of standards that serve as the foundation for the definition and the description of the fundamental concepts that support the development of geographic applications and the interoperability between them. It includes

— this reference model and any additional part (e.g. ISO/TS 19101-2) and

— the International Standard about conceptual schema languages used for the definition of the ISO geographic information standards.

The following aspects are part of Meta-meta:Semantic but are excluded from the scope of ISO geographic information standards:

— *standards about already defined datatypes and codes;*

— *the UML specifications;*

— *the OCL specifications;*

— *the OWL specifications.*

8.3.2 Meta:Semantic

Meta:Semantic shall consist of standards that define and describe fundamental concepts that are necessary to define, describe, and represent geographic information. These fundamental concepts serve as the domain ontology in geographic information. These concepts allow the consistent definition of geographic features with their specific characteristics. Meta:Semantic includes

— the standard defining GFM, including the rules to develop consistent application schemas,

— standards related to the definition of spatial concepts, including geometric and topological concepts, operators for reasoning with geometry and topology, coverage geometry, observations and measurements, linear referencing, etc.,

— standards related to the definition of temporal concepts as well as spatiotemporal concepts,

— standards related to definition of concepts for the description of spatial referencing systems either by coordinates, geographic identifiers, place identifiers, etc.,

— standards defining concepts for the description of geographic information quality,

— standards for the definition of data product specifications, and

— standards defining concepts and rules or methodologies to develop consistent application ontologies on the basis of GFM. This includes methodologies for feature cataloguing, feature concept dictionaries, classification systems, etc.

8.3.3 Application:Semantic

Application:Semantic shall consist of the definition of geographic information concepts that are specifically defined for an application. These concepts are defined in compliance with the Meta:semantic level and can be defined as part of International Standards, national standards, within specific communities, and others. Application:Semantic includes

— application schemas,

— application ontologies in specific areas (e.g. land cover classification, land administration, addressing, environment variables, hydrology, geodetic codes and parameters, etc.),

- data product specifications, and
- metadata models (e.g. vector data metadata, imagery metadata, etc.).

8.3.4 Instance:Semantic

Instance:Semantic is included in the reference model conceptual framework for completeness but is not part of the scope of this part of ISO 19101. It shall consist of the data that has been captured and is maintained in geographic information systems, databases, files, etc. The data complies with the application schemas, ontologies, and the metadata model defined in the Application:Semantic level. Instance:Semantic includes

- dataset, including features, spatial and temporal objects, and position,
- metadata instance document, and
- data quality description.

8.4 Reference model — Syntactic foundation

8.4.1 Meta-meta:Syntactic

Meta-meta:Syntactic shall consist of standards that serve as the foundation for the definition of rules and methodologies for encoding geographic information into formats to enable the communication or exchange of data.

The following aspect is shown as part of Meta-meta:Syntactic but is excluded from the scope of ISO geographic information standards.

- *XML specifications*.

8.4.2 Meta:Syntactic

Meta:Syntactic shall consist of standards defining specific languages and rules for the encoding of geographic information as well as for their portrayal as maps or charts, in accordance with the semantic foundation. Meta:Syntactic includes

- standards defining encoding languages and rules for geographic data (e.g. vector data, imagery, etc.) and
- standards defining portrayal rules and portrayal catalogue definition.

8.4.3 Application:Syntactic

Application:Syntactic shall consist of definitions of standardized representations of geographic information. Standardized representation of geographic information complies with the Application:Semantic level. Application:Syntactic includes

- standards describing textual encodings,
- standards describing binary encodings,
- standards describing XML representations of data (e.g. Geography Markup Language, metadata XML implementation, register XML implementation, feature catalogue XML implementation, Rights Expression Language, etc.), and
- portrayal rules and catalogues.

8.4.4 Instance:Syntactic

Instance:Syntactic is included in the reference model conceptual framework for completeness but is not part of the scope of this part of ISO 19101. It shall consist of instance documents encoded or portrayed according to the Application:Syntactic level, i.e. application XML schemas or portrayal catalogues and rules. Instance:Syntactic includes

— encoded vector data instances,

— encoded image data instances,

— encoded grid data instances,

— encoded coverage data instances,

— encoded metadata instances,

— maps (digital images, paper maps, etc.), and

— charts (digital images, paper maps, etc.).

8.5 Reference model — Service foundation

8.5.1 Meta-meta:Service

Meta-meta:Service shall consist of standards that serve as foundation for the definition of rules and methodologies for the development of geographic information processing and services for, but not limited to, the discovery, the access, and the processing of geographic information. Meta-meta:Service includes

— reference model for services,

— reference model for location-based services, and

— reference model for ubiquitous public access.

8.5.2 Meta:Service

Meta:Service shall consist of standards defining rules and methodologies for the development of geographic information processing and services. Meta:Service includes

— standards on services.

8.5.3 Application:Service

Application:Service shall consist of definitions of standardized geographic information services. Capabilities of the service agree with the Application:Semantic level. Application:Service includes

— standards for geographic human interaction services,

— standards for geographic model/information management services,

— standards for geographic workflow/task management services,

— standards for geographic processing services:

  — spatial (i.e. vector, coverage, and imagery and gridded data);

  — thematic (e.g. Web services for mapping, delivering data about features, and filtering data);

  — temporal;

   — metadata, and

— standards for geographic communication services.

8.5.4 Instance:Service

Instance:Service is included in the reference model conceptual framework for completeness but is not part of the scope of this part of ISO 19101. It shall consist of service instances (including Web services) complying with services defined as part of Application:Service. Instance:Service includes

— services and

— Web services.

8.6 Reference model — Procedural standards

8.6.1 Meta-meta:Procedural

Meta-meta:Procedural shall consist of standards that serve as foundation for defining standards describing an ordered series of steps to accomplish a specified task.

The following aspect is shown as part of Meta-meta:Procedural but is excluded from the scope of ISO geographic information standards.

— ISO/IEC Directives, *Part 2: Rules for the structure and drafting of International Standards*[19].

8.6.2 Meta:Procedural

Meta:Procedural shall consist of standards defining frameworks or structures from which procedural standards are based and developed. Meta:Procedural includes

— standards about conformance and testing.

8.6.3 Application:Procedural

Application:Procedural shall consist of definitions of standard procedures that apply in some context. Application:Procedural includes

— standards about the terminology used in the ISO geographic information standards, and the terminology register,

— standards about definition of profiles,

— standards about procedures for registration, and

— standards about procedures for quality management and assessment.

8.6.4 Instance:Procedural

Instance:Procedural is included in the reference model conceptual framework for completeness but is not part of the scope of this part of ISO 19101. It shall consist of procedures defined for a specific context. Instance:Procedural can include

— specifications defining steps for vector or raster data capture, and

— specifications defining steps for processing data for a given purpose.

8.7 Uses of the reference model

The ISO geographic information reference model provides a high-level decomposition of those aspects of geographic information that are addressed by the ISO geographic information standards. Such decomposition allows classifying the contribution of standards to the framework for interoperability of geographic information and at what level. Based on this decomposition, Annex F lists the standards covered by the ISO geographic information standards.

9 Profiles

9.1 Introduction to profiles

The comprehensiveness and large number of options available in various base standards make it difficult to combine them for practical applications. The concept of profile shall be used for establishing such combinations, thereby providing a mechanism to use the ISO geographic information standards in real applications. The concept and development of profiles of the ISO geographic information standards shall follow the guidelines set forth in ISO/IEC 10000-1[20].

A profile shall integrate a set of base standards and/or modules (predefined subsets) of base standards to meet a specific implementation requirement. A base standard is any ISO geographic information standard or any other information technology standard that can be used as a source for components from which a profile can be constructed. A module is a predefined set of elements in a base standard that can be used to construct a profile. The modular structure of the ISO geographic information standards makes the creation of profiles more efficient and transparent, and promotes interoperability.

9.2 Use of profiles

Profiles shall be defined for conforming subsets or combinations of the ISO geographic information standards and/or subsets thereof, used to perform specific functions. Profiles shall identify the use of particular options available in the base standards and provide a basis for development of uniform, internationally recognized conformance tests.

9.3 Relationship of profiles to base standards

The ISO geographic information standards shall address the development of profiles as a procedural standard (see ISO 19106[24]). This procedural standard shall provide the principles for profiles of the standards in the ISO geographic information standards, possibly in combination with one or more other IT base standards, guidelines for their creation, a classification scheme, and a mechanism and procedures for their registration. It shall also provide the concept of modularity, which has been applied to the ISO geographic information standards to enable the efficient use of components thereof to build a profile.

Annex A
(normative)

Abstract test suite

A.1 Scope in ISO geographic information standards and profiles

The test for scope in ISO geographic information standards and profiles is as follows:

a) Test purpose: Verify that the scope of the ISO geographic information standard or profile defines which aspects of geographic information it standardizes with respect to the ones listed in 6.2 of this part of ISO 19101. For aspects not listed in 6.2 of this part of ISO 19101, verify that justifications are provided.

b) Test method: Inspect the scope of the ISO geographic information standard or profile and identify to which aspects of 6.2 of this part of ISO 19101 it refers, or identify justifications for all additional aspects.

c) Reference: 5.1 and 6.2.

d) Test type: Basic test.

A.2 Conceptual formalism

The test for the applicable conceptual formalism is as follows:

a) Test purpose: Verify that the conceptual formalism used in the standard or profile is object-oriented.

b) Test method: Inspect that the concepts in the standards or profiles are defined consistently with the object-oriented methodology.

c) Reference: 7.2.

d) Test type: Basic test.

A.3 Ontology graphical language

A.3.1 UML class and package diagrams

The test for UML class and package diagrams is as follows:

a) Test purpose: Verify that class and package diagrams in the standard or profile are described primarily using UML.

b) Test method: Inspect that all diagrams defining classes and packages in the standard or profile are represented in compliance with UML.

c) Reference: 7.3.1.

d) Test type: Basic test.

A.3.2 Requirements for the use of UML and OCL

The test for the requirements for the use of UML and OCL in ISO geographic information standards is as follows:

a) Test purpose: Verify that ISO/TS 19103 sets which version of UML and OCL the ISO geographic information standards shall use as well as the additional requirements and the additional functionalities to support the development of ISO geographic information standards.

b) Test method: Inspect that ISO/TS 19103 includes requirements about the versions of UML and OCL to be used in ISO geographic information standards.

   Inspect that ISO/TS 19103 identifies the additional requirements clearly and that rules and guidelines are provided for each requirement.

c) Reference: 7.3.1.

d) Test type: Basic test.

A.4 Ontology lexical language

A.4.1 Rules for Web Ontology Language (OWL)

The test for rules for Web Ontology Language (OWL) is as follows:

a) Test purpose: Verify that ISO 19150-2 sets the rules required to derive OWL ontologies from ISO geographic information UML class and package diagrams.

b) Test method: Inspect that ISO 19150-2 has all the required rules for the derivation in OWL of the UML class and package diagrams complying to ISO/TS 19103 requirements.

c) Reference: 7.3.2.

d) Test type: Capability test.

A.4.2 OWL ontologies

The test for Web Ontology Language (OWL) is as follows:

a) Test purpose: Verify that UML class and package diagrams are also described in OWL ontologies.

b) Test method: Inspect if the standard or profile includes an OWL description of its UML diagrams or a reference to the OWL resource on the Web.

c) Reference: 7.3.2.

d) Test type: Capability test.

A.4.3 UML models and OWL ontologies co-existence

The test for UML models and OWL ontologies co-existence is as follows:

a) Test purpose: Verify that ISO geographic information UML class and package diagrams and their respective OWL ontologies are both present as ISO geographic information resources.

b) Test method: Inspect that each ISO geographic information UML class and package diagram has a corresponding OWL ontology and both are maintained in a respective repository that can be made accessible on the Web.

c) Reference: 7.3.2.

d) Test type: Capability test.

A.5 Reference model — Meta-meta:Semantic foundation standards

The test for reference model is as follows:

a) Test purpose: Verify that the nature of ISO geographic information standards and profiles along with the level and foundation are clearly identified as such.

b) Test method: Inspect that the scope of the ISO geographic information standard or profile identifies the aspect it addresses in accordance with 8.3.1 to 8.6.4 and identifies the levels and foundations it belongs to by using the following terms:

— Meta-meta:Semantic foundation;

— Meta:Semantic foundation;

— Application:Semantic foundation;

— Instance:Semantic foundation;

— Meta-meta:Syntactic foundation;

— Meta:Syntactic foundation;

— Application:Syntactic foundation;

— Instance:Syntactic foundation;

— Meta-meta:Service foundation;

— Meta:Service foundation;

— Application:Service foundation;

— Instance:Service foundation;

— Meta-meta:Procedural;

— Meta:Procedural;

— Application:Procedural;

— Instance:Procedural.

c) Reference: 8.3.1, 8.3.2, 8.3.3, 8.3.4, 8.4.1, 8.4.2, 8.4.3, 8.4.4, 8.5.1, 8.5.2, 8.5.3, 8.5.4, 8.6.1, 8.6.2, 8.6.3, and 8.6.4.

d) Test type: Basic test.

A.6 Profile

A.6.1 Profile

The test for profile is as follows:

a) Test purpose: Verify that subsets or combinations of ISO geographic information standards are defined as a profile.

b) Test method: Inspect that subsets or combinations of ISO geographic information standards fulfil the requirements stated in ISO 19106 and identify the particular use of the options of the base standards.

c) Reference: 9.1 and 9.2.

d) Test type: Basic test.

A.6.2 Development of a profile

The test for development of a profile is as follows:

a) Test purpose: Verify that the profile is developed in compliancy with the guidelines set forth in ISO/IEC 10000-1[20].

b) Test method: Inspect if ISO 19106 integrates required guidelines from ISO/IEC 10000-1.

c) Reference: 9.1.

d) Test type: Basic test.

A.6.3 Integration of base standards and/or modules

The test for integration of base standards and/or modules is as follows:

a) Test purpose: Verify that the profile identifies the set of base standards and/or modules (predefined subsets) of base standards it is referring to and the specific implementation requirement it addresses.

b) Test method: Inspect if ISO 19106 includes a requirement in the definition of a profile that the profile's scope clause identifies the set of base standards and/or modules (predefined subsets) of base standards to which it refers and the specific implementation requirement it addresses.

c) Reference: 9.1.

d) Test type: Basic test.

A.6.4 Relationship of profiles to base standards

The test for relationship of profiles to base standards is as follows:

a) Test purpose: Verify that ISO geographic information standards address the development of profiles as a procedural standard.

b) Test method: Inspect that ISO geographic information standards define a procedural standard that provides (1) the principles for profiles of the standards in the ISO geographic information standards, possibly in combination with one or more other IT base standards, (2) guidelines for creation of profiles, (3) a classification scheme for profiles, and (4) a mechanism and procedures for their registration.

c) Reference: 9.3.

d) Test type: Basic test.

Annex B
(informative)

Layers of interoperability

B.1 General

In the previous version of this reference model, interoperability has been decomposed into six layers[2] as illustrated in Figure B.1:

— network protocols;

— file systems;

— remote procedure calls;

— search and access databases;

— geographic information systems (GIS);

— semantic interoperability.

In this decomposition, each layer is dependent on the layers that underlie it. As such, if there is a problem of interoperability at one layer, all the above layers will suffer from it. To facilitate the transition between these layers and the types of heterogeneity presented in 5.1.2, the six layers are described hereafter and a correspondence with the types of heterogeneity is provided in Figure B.1.

B.2 Network protocols

Network protocol interoperability describes basic communication between systems within a network of computers and, as such, addresses issues of system heterogeneity. A computer network is composed of hardware and software. The hardware consists of network interface cards and cables linking computers together whereas the software consists of the network protocols, which are the rules and procedure systems used to communicate on the network. Protocols prescribe communication on two levels. At the higher level, there is the communication between applications. The lower level describes the transmission of signals on the network. Interoperability is required at this level to ensure signals can be sent and received, signals are timely, networks are expandable, and security is intact.

B.3 File systems

File system interoperability allows files from a different system to be opened and displayed in their native format. Although file system interoperability allows transfer of and access to files, it also refers to directory naming conventions, access control, access methods, and file management. This level of interoperability is also concerned with system heterogeneity issues.

B.4 Remote procedure calls

Remote procedure calls refer to a set of operations that execute procedures on remote systems. This form of interoperability standardizes how programs run under another operating system. It allows a user to execute programs on a remote system, independently of any operating system. Remote procedure calls again addresses system heterogeneity issues.

B.5 Search and access databases

Search and access databases go beyond system interoperability as defined by the above first three levels by providing the ability to query and manipulate data in a common database that is distributed over different platforms, i.e. distributed computing platform. Interoperability challenges include the location and access to the stored data. Although the various database management systems also have issues related to system heterogeneity, this level of interoperability aims at overcoming syntactic and structural heterogeneity issues to seamlessly access databases despite the locations, the data structures, and the query languages of the database management systems. For example, middleware using SQL can connect various databases on different platforms and of different database management systems.

B.6 Geographic information systems

Similarly to the previous level of interoperability, i.e. search and access databases, this level of interoperability is also concerned with syntactic and structural heterogeneity issues but specific to geographic information. GISs are specific to geographic information, which deals also with spatially and temporally referenced data. Interoperability between GISs provides transparent access to such data, the sharing of spatial databases, and other services regardless of the platform. To achieve interoperability between GISs, real world phenomena need to be abstracted and represented using a common mechanism, services shall follow a common specification model, and institutional issues solved in an information communities model.

B.7 Semantic interoperability

Semantic interoperability is the highest level of interoperability in geographic information that deals with semantic heterogeneity issues. Typically, applications are defined with different views of the world, each one addressing a different context and purpose, and, accordingly, same real world phenomena might be depicted with different semantics. This level of interoperability addresses the proper exchange and use of geographic information between systems. Semantic interoperability in geographic information refers to an effective bi-directional communication process between two systems in which data as either queries or responses are interpreted correctly and the response answers the query germanely.

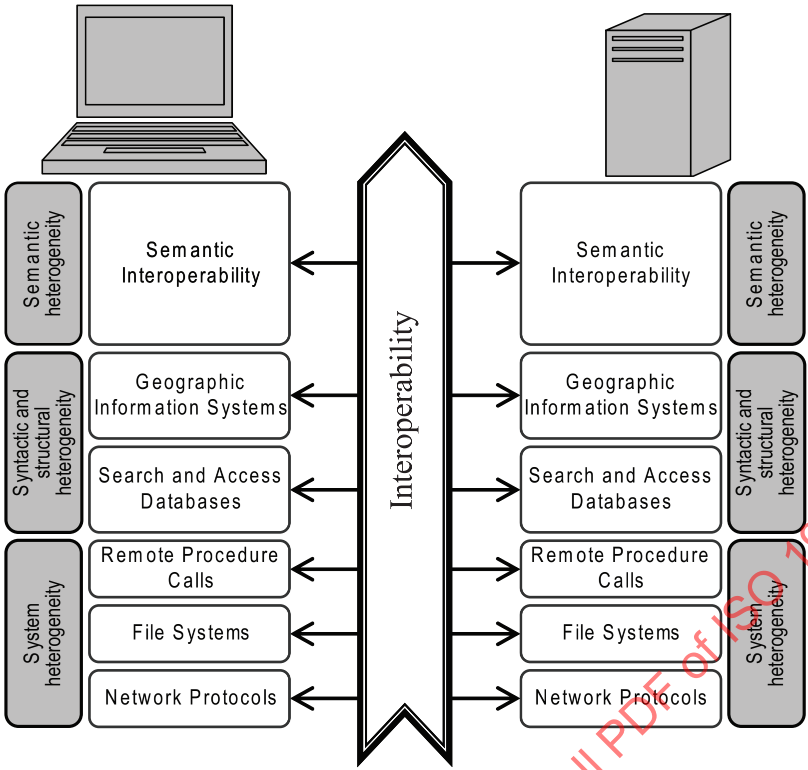

Figure B.1 — Levels of interoperability (adapted from Reference [2])

Annex C
(informative)

Interoperability of geographic information in e-government

C.1 e-government

E-government consists of governance, information and communication technology (ICT), business process re-engineering, and citizens at all levels of government (city, state/province, national, and international).

Geographic information is an important part of e-government data, and the linkage of geographic information with other kinds of information in an interoperable way becomes very important within the context of e-government activities. The technical and semantic interoperability of geographic information, for example, would enhance cross-border cooperation, environmental monitoring, and the coordination of disaster relief.

In the context of SDI and as described in 5.1, interoperability is the ability to exchange and manipulate geographic information across distributed systems without having to consider the heterogeneity of the information source (e.g. format and semantics).

The European Interoperability Framework (EIF)[8] defines a set of recommendations and guidelines for e-government services so that public administrations, enterprises, and citizens can interact across borders, in a pan-European context. In EIF, interoperability is defined as such: ability of information and communication technology (ICT) systems and of the business processes they support to exchange data and to enable the sharing of information and knowledge. In this context, an interoperability framework is defined as a set of standards and guidelines that describe the way in which organizations agree to interact with each other.

The goals of such e-government activities can be summarized by the following aspects:

— to promote and support delivery of public services by fostering cross-border and cross-sectoral interoperability;

— to guide public administration in their work to provide public services, both to businesses and to the citizens;

— to complement and tie together various national interoperability frameworks at the regional or global level.

To achieve interoperability at this level, technological, organizational, financial, and operational frameworks are required. This annex addresses the technological framework only.

C.2 Conceptual model for e-governmental services

C.2.1 General

The creation and operation of e-governmental services can be represented in a conceptual model (see Figure C.1). The model emphasizes a building-block approach for setting up services, allowing for the interconnection and reusability of service components when building new services. Splitting functionalities into basic services with well-defined interfaces, designed to be reused, simplifies the aggregation of services and the reuse of components, and avoids duplication.

Geographic information services will be among the basic e-government services, and can support both geographic and non-geographic e-government services and/or be major components in such services.

Figure C.1 describes a conceptual model for e-government services which consist of several components. When integrating geographic data and services into such an approach, it is important to identify geographic information solutions (standards) which fit into the components of such a framework.

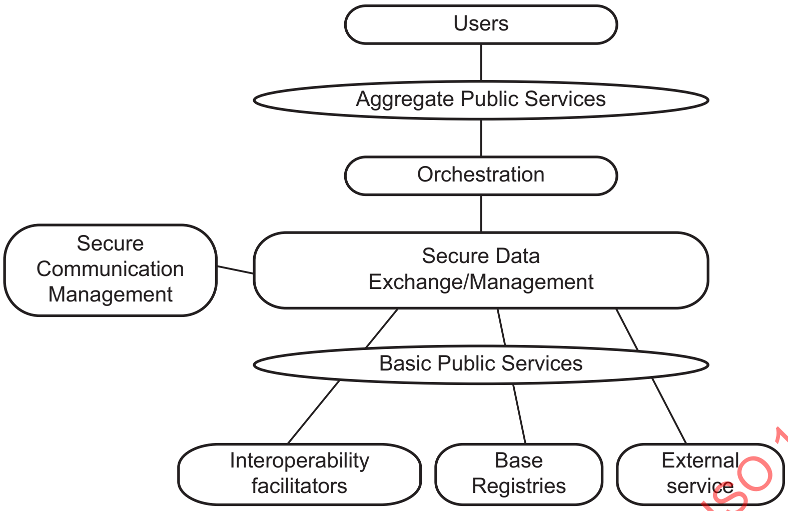

Figure C.1 — Conceptual model for public services (from Reference [8])

C.2.2 Basic public services

C.2.2.1 General

"Basic services" constitutes the lowest level of the model. These services are developed mainly for the direct use by the public administration (between government agencies), but also by their direct customers, i.e. government and citizens and government and businesses. They are also intended to be reused for providing aggregation of services.

C.2.2.2 Interoperability facilitators

Interoperability facilitators provide tools and services such as translation between exchange formats, protocols, and languages.

One example of integration with geographic information communities is the mapping between ISO 19136 and Resource Description Framework (RDF), which is the underlying structure for linked data (see C.3). Another possible example is the mapping between ISO/TS 19139 and Dublin Core[23].

C.2.2.3 Base registries

The base registries provide reliable data about the underlying information items, for example buildings, locations, and roads. They are the fundamental data that compose the Basic Public Services.

For geographic information communities, spatial datasets are important input to these base registries. Depending on the underlying implementation platform used to implement registries, different interoperability facilitators might be required to enable interoperation between registries. Examples of implementation platforms, which are often applied in e-government activities, are ebXML RIM and ebXML RS.

C.2.2.4 External services

These services are provided by external parties, like payment services or connectivity services provided by telecommunication providers.

C.2.3 Secure data exchange layer/secure communication management

The secure data exchange layer with secure communication management (referred to as secure data exchange/management in Figure C.1) provides all basic public services. It manages authentication, certification, and digital rights.

From a geographic information point of view, ISO 19149[29] and ISO 19153[30] are normatively referencing the underlying IT standards and constitute the necessary extension for the geospatial domain, and are suitable in e-government solutions.

C.2.4 Orchestration

The orchestration level identifies the automatic coordination of applications and particularly services that comprise a business process, and it is also the basis for aggregating services. This level enables combination of services in a dependent series to achieve larger tasks, ending up in aggregate services.

C.2.5 Aggregate public services layer

These aggregated public services are constructed by grouping a number of basic services in a secure and controlled way. From a user point of view, it can be accessed as a single service. In order to ease the aggregation of services, a service catalogue providing the necessary service metadata would be a useful interoperability facilitator. From the geographic point of view, ISO 19119[27] explains this by

— defining a model for combining services to achieve larger tasks,

— addressing the syntactic issues of service chaining, and

— defining service metadata.

C.2.6 Benefit

Identification and definitions of the geographic information components to such a conceptual model of the interoperability framework enable the integration of geographic data and services to more general activities. It is particularly important to define and get acceptance for geographic services as basic public services, being building blocks for aggregated services in the e-government domain.

C.3 e-government through linked data

Linked data is a method for publishing structured data, so that it can be interlinked and become more useful. It builds upon standard Web technologies, such as HTTP and URIs. However, rather than using them to serve Web pages for human readers, it extends them to share data in a way that can be read automatically by computers. This enables data from different sources to be connected and queried.

Linked data is one of the most important technologies to link geographic information with other kinds of governmental information. It is part of the Semantic Web development. Linked data is about applying the principles and architecture of the Web to data.

An advantage of the linked data approach is that it uses concepts and technologies which are well understood, proven in practice, and have a low entry barrier. As it is based on proven and widely used Web technologies, it has good potential to make geographic information accessible to new applications.

Open data is a philosophy and practice requiring that certain information be freely available to everyone, without restrictions from copyright, patents, or other mechanisms of control.

NOTE The goal of the W3C SWEO Linking Open Data community project is to extend the Web with a data commons by publishing various open datasets as RDF on the Web and by setting RDF links between data items from different data sources.

RDF links enable the navigation from a data item within one data source to related data items within other sources using a Semantic Web browser. RDF links can also be followed by the crawlers of Semantic

Web search engines, which might provide sophisticated search and query capabilities over crawled data. As query results are structured data and not just links to HTML pages, they can be used within other applications.

The increasing work with geographic information in the context of Semantic Web technologies is also reflected in new standardization activities (e.g. ISO/TS 19150-1,[35] ISO 19150-2,[31] and SPARQL geospatial extension – GeoSPARQL[41]).

Spatial Data Infrastructure (SDI) concepts and linked data do not exclude but complement each other. Neither is a replacement of the other. GIS applications will continue to use existing encodings like Shapefile,[7] GML,[33] KML,[40] GeoRSS,[9] etc.

Annex D
(informative)

Foundation standards for SDI

D.1 General

Interoperability of geographic information has been widely achieved through the deployment of SDIs[5][36]. An infrastructure is an essential resource required for a specific activity. This is the case for the road infrastructure for ground transportation, the underground pipes for water distribution in cities, and the electrical facilities for generating and distributing electricity. In geographic information, SDIs are not different to these infrastructures. An SDI is meant as a networked environment (e.g. Internet) that supports the easy and coordinated access to geographic information and geographic information services[14][36]. An SDI has the capability to

— host geographic data (including attributes) and services,

— host documentation about data and services, i.e. metadata,

— discover geographic data and services,

— visualize geographic data,

— evaluate geographic data and services,

— access geographic data and services, and

— Web data processing.

An SDI can be viewed as a collaborative framework of disparate information systems that contain resources that stakeholders desire to share[5]. It is composed of policies, technologies, standards, and human resources, for the collection, processing, management, access, delivery, and use of geographic information. It has been mainly developed based on RM-ODP[17].

D.2 RM-ODP viewpoints in relation with SDI

RM-ODP consists of a framework of five viewpoints (Figure D.1) that are

— enterprise viewpoint,

— information viewpoint,

— computational viewpoint,

— engineering viewpoint, and

— technology viewpoint.

The enterprise viewpoint addresses the purpose and the scope, the policies, the responsibilities, and the business process of an SDI, i.e. it defines the role of the SDI in its environment. The information viewpoint focuses on the information that is accessible from the SDI. The computational viewpoint is related to the functional SDI decomposition into services with interfaces and operations. The engineering viewpoint relates to the interaction between data and services, and system interconnections. The technology viewpoint is concerned with the specifically chosen technology for the SDI implementation.

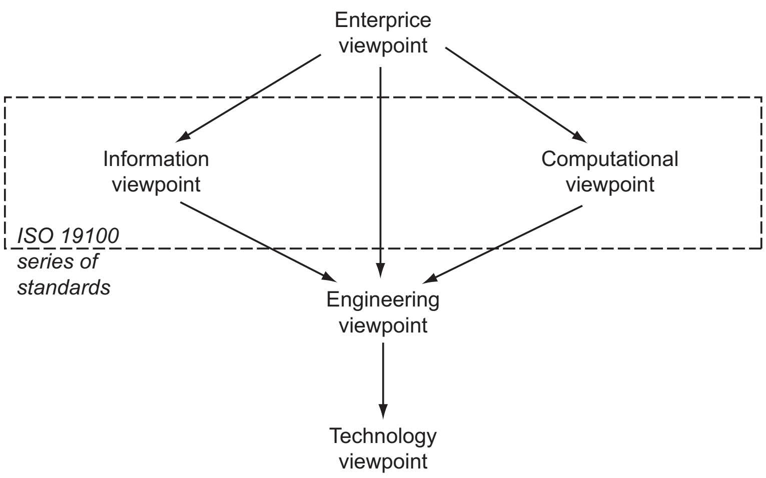

Figure D.1 — RM-ODP viewpoints

Standards in geographic information are especially concerned with the information and computational viewpoints. From an information viewpoint, the ISO geographic information standards bring rules, methodologies, and models from the meta-meta (e.g. UML), the meta (e.g. conceptual schema language, GFM), the application (e.g. application schema, feature catalogue, metadata), to the instance level (e.g. dataset and metadata dataset) (see 8.3) to describe geographic features (see Figure D.2).

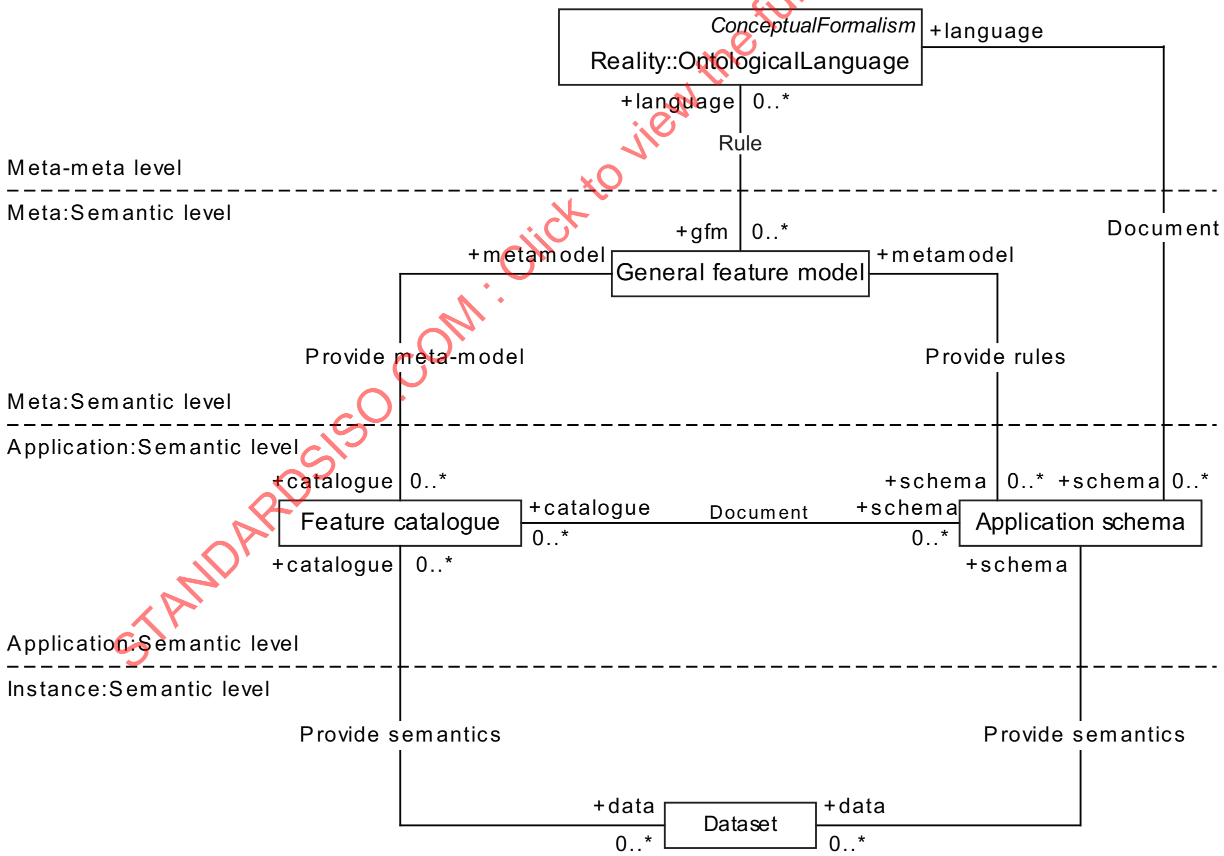

Figure D.2 — Information viewpoint and standards

From a computational viewpoint, the ISO geographic information standards bring a definition of the interaction with services as part of a larger system in the form of models from the meta-meta (e.g. reference models), the meta (e.g. standards on services), the application (e.g. Web mapping services, Web feature services), to the instance level (e.g. services) (see 8.5) to describe geographic processing and services (see Figure D.3).

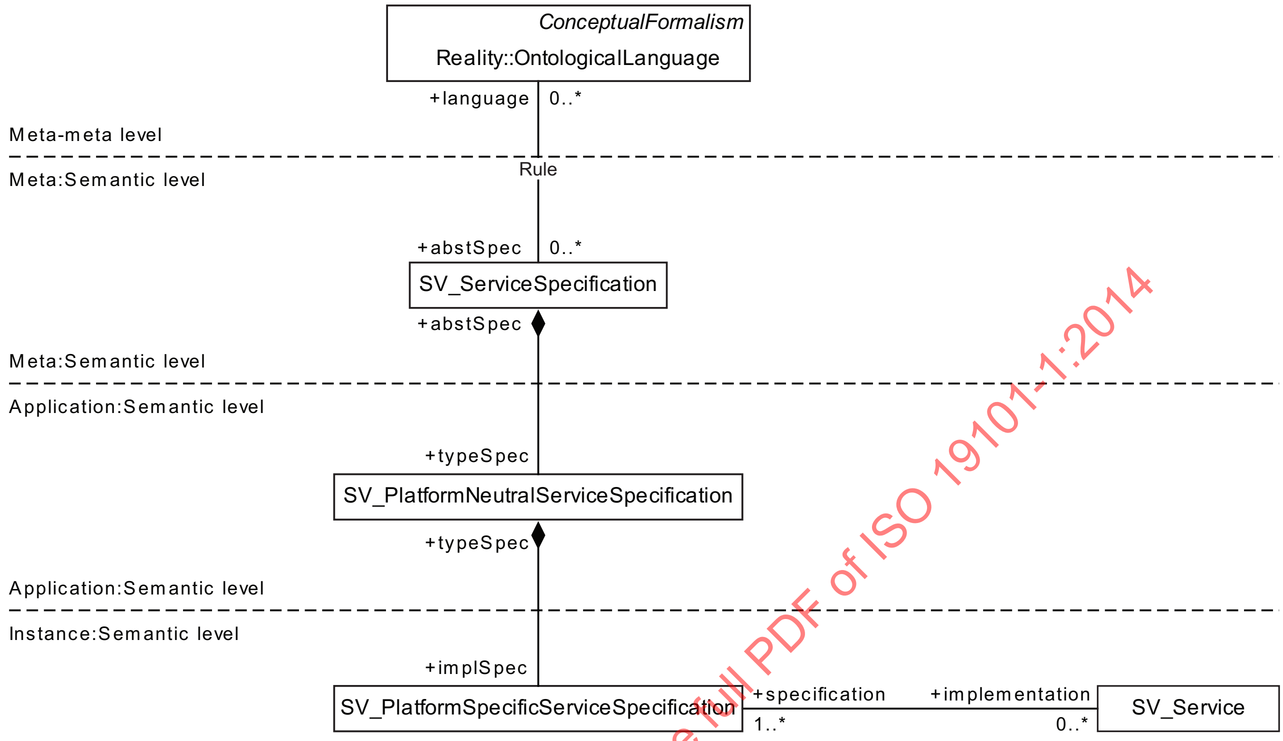

Figure D.3 — Computational viewpoints and standards

Annex E
(informative)

Abstraction of the real world in geographic information

E.1 General

This annex describes the concepts that underlie the abstraction of real world phenomena in the ISO geographic information standards. At the beginning, it identifies the principles that underpin conceptual modelling. Next, it provides a description of the abstraction of real world phenomena. After, it identifies the ontological languages to be used in the ISO geographic information standards for describing models of geographic information and geographic information services. It further presents uses of ontologies to support interoperability of geographic information. It explains finally the fundamental concept of model integration for the effective use of ISO geographic information standards for integrating geographic information in distributed computing environments.

The information contained in this annex is intended for developers of standards in geographic information, for users of the ISO geographic information standards who wish to understand how ontology and conceptual modelling are used in this family of standards, and for developers of GIS software.

Developers of the ISO geographic information standards and developers of standards intended to be consistent with the ISO geographic information standards should follow this annex on the use of ontological languages for geographic information. Users and developers need to understand the use of ontology languages in the ISO geographic information standards in order to properly use this family of standards and its associated profiles and product specifications to develop geographic information, software, applications, and services that are interoperable.

E.2 Conceptual modelling

The principles that govern the use of conceptual modelling and the development of conceptual schemas in the ISO geographic information standards are based on and/or adapted from the Conceptual Schema Modelling Facility (CSMF)[18] (see Annex G). These principles are:

— The "100 %" principle states that all (100 %) of relevant structural and behavioural rules about the universe of discourse shall be described in a conceptual schema. Thus, the conceptual schema defines the universe of discourse.

— The "Conceptualisation" principle states, according to ISO/TR 9007,[32] that a conceptual schema should contain only those structural and behavioural aspects that are relevant to the universe of discourse. All aspects of physical external or internal data representation should be excluded. This requires the production of a conceptual schema, which is independent with respect to physical implementation technologies and platforms.

— The "Helsinki" principle states that any meaningful exchange of verbal or written statements should be based upon an agreed set of semantic and syntactic rules. All statements in a conceptual schema shall be formulated and interpreted using such an agreed set of rules. The conceptual schema languages identified in Clause 7 should provide the basic set of semantic and syntactic rules for representation of geographic information in conceptual schemas developed as part of the ISO geographic information standards. ISO geographic information standards, such as ISO/TS 19103[33] and ISO 19109[25]. describe how conceptual schema and ontological languages are applied to create application schemas for geographic applications.

— The principle of "Use of a concrete conceptual schema language syntax" states that a formally defined conceptual schema language syntax shall be used to represent information in a conceptual schema. Clause 7 identifies the ontological languages that are used for the ISO geographic information standards.

— The "self-description" principle states that normative constructs defined in an International Standard, and in this case the ISO geographic information standards, and related profiles shall be capable of self-description.

These principles provide the necessary guidelines to abstract and describe the reality in parts required for application. From these principles, the abstraction and description of reality has been formerly depicted from a conceptual modelling perspective. It is now refurbished from an ontological perspective where ontologies become the semantic component that is machine processable to support interoperability over the Web and Semantic Web as well as across disciplines.

These principles also underlie the use of the ontological languages identified for the representation of geographic information and geographic information services in the ISO geographic information standards.

Geographic information is about the representation of the reality by the use of digital data. The reality exists independently of people who observe it. It cannot be represented as a whole because of its complexity, i.e. the number of entities that compose it and the relationships that exists between the entities. As a consequence, it is rather described in subsets according to a specific context, e.g. a set of features such as watercourses, lakes, or islands might constitute a portion of the real world. Typically, people use concepts to abstract portions of the reality and to describe it formally. These concepts are then used to communicate information about that portion of reality with others.

The representation of reality has been widely depicted in the model shown in Figure E.1. In this model, a universe of discourse consists of a selected piece of the real world that a human being wishes to describe in a conceptual model. The universe of discourse includes things (e.g. watercourses, lakes, islands, property boundaries, property owners, and exploitation areas) and their characteristics (properties, functions) and relationships that exist among such features.

The conceptual schema is a formal representation of a conceptual model in a conceptual schema language. A conceptual schema language is a formal language containing the required linguistic constructs to describe a conceptual model in a conceptual schema. A conceptual schema that defines how a universe of discourse is described as data is called an application schema. A conceptual formalism defines the concepts and the grammar (e.g. rules, constraints, inheritance mechanisms, events, functions, processes, etc.) required by a conceptual schema for the description of a universe of discourse. More than one conceptual schema language, either lexical or graphical, can adhere to and be mapped to the same conceptual formalism.

More recent works on the abstraction and representation of reality for their use in information systems have tackled the issue from an ontological perspective[11][12][13]. As such, the above description of the representation of reality is updated accordingly in Figure E.2. Figure E.2 depicts the abstraction of the real world in a UML class diagram. A universe of discourse is a subset of the real world that is subject to some context. The universe of discourse is described by the way of ontology. In this part of ISO 19101, an ontology refers to a formal representation of phenomena of a universe of discourse with an underlying vocabulary including definitions and axioms that make the intended meaning explicit and describe phenomena and their interrelationships.

The conceptual formalism defines the concepts and the grammar (e.g. rules, constraints, inheritance mechanisms, events, functions, processes, etc.) that make up an ontological language. It provides a basis for the formal definition of all knowledge considered relevant to an information technology application. Object-oriented modelling as described in UML is the conceptual formalism used for the ISO geographic information standards.

An ontological language implements a conceptual formalism to provide the semantic and syntactic elements used to describe an ontology rigorously in order to convey meaning consistently. More than one ontological language, either lexical or graphical, can adhere to and be mapped to the same conceptual formalism. In Figure E.2, UML and OWL are shown because they are of specific interest and purpose of the ISO geographic information standards.

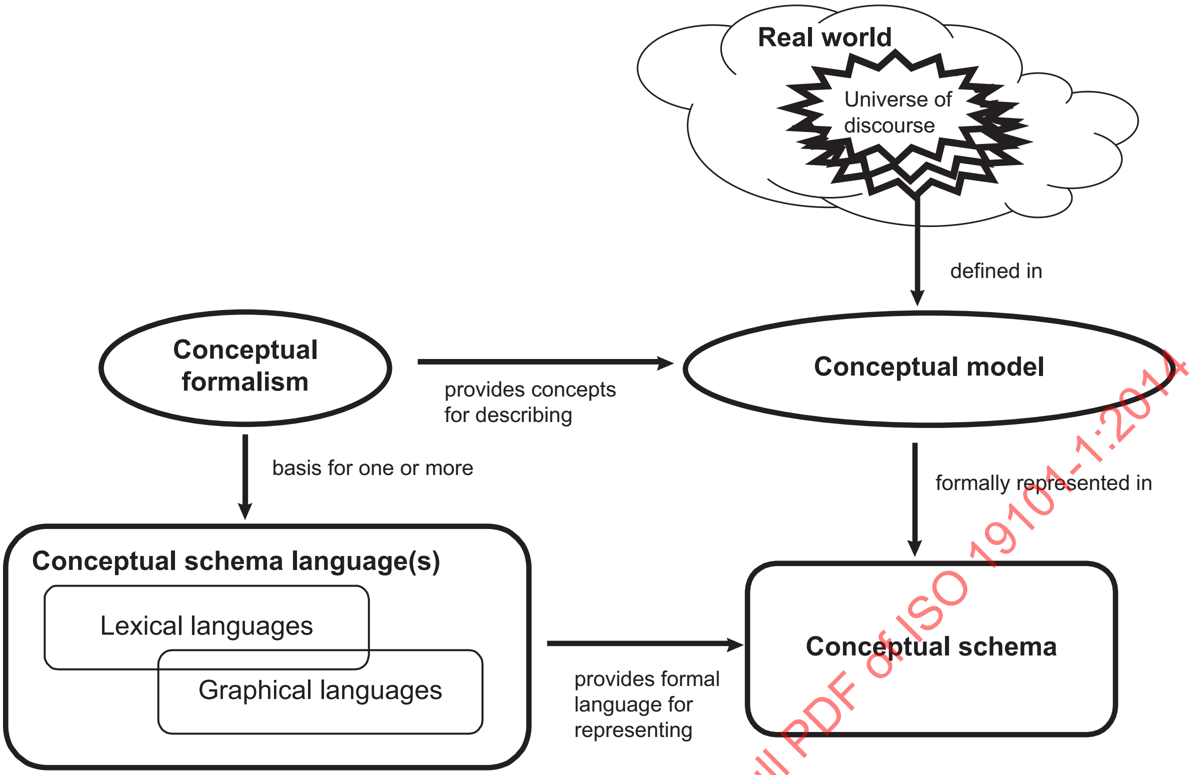

Figure E.1 — From reality to conceptual schema

Ontologies provide a foundation for describing information. Ontologies can be read by computer systems as well as human beings. The use of ontological languages to develop ontologies is thus fundamental in the standardization of geographic information. Ontologies are frequently developed as conceptual models, and global, domain, and application ontologies as conceptual schema.

The ISO geographic information standards develop ontologies by the way of conceptual modelling primarily to serve the following purposes:

a) to define geographic information and geographic information services rigorously;

b) to standardize the definition of geographic information and geographic information services so that systems interoperate in distributed computing environments such as the Web.

To achieve the second purpose, conceptual schemas standardized in the ISO geographic information standards serve as the basis for defining consistent ontologies for supporting inter-communication between geographic information services and systems.