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Geographic information — Training data markup language for artificial intelligence —

Part 1: Conceptual model

Information géographique — Langage de balisage des données d'entraînement pour l'intelligence artificielle — Partie 1: Modèle conceptuel

FDIS stage

Contents

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~~document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part ~~2 (see www.iso.org/directives~~ 2 (see www.iso.org/directives).

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~~The Training Data Markup Language for Artificial Intelligence (TrainingDML-AI) was originally developed within the Open Geospatial Consortium, Inc. (OGC).~~ This document was prepared by Technical Committee ISO/TC 211, *Geographic information/Geomatics*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 287, *Geographic Information*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement) and in collaboration with the Open Geospatial Consortium Inc. (OGC).~~OGC.~~

A list of all parts in the ISO 19178 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at ~~www.iso.org/members.html~~www.iso.org/members.html.

Introduction

This document aims to develop the UML model and encodings for geospatial machine learning training data. Training data play a fundamental role in Earth Observation (EO) Artificial Intelligence Machine Learning (AI/ML), especially Deep Learning (DL). ~~It is~~Training data are used to train, validate~~,~~ and test AI/ML models. This document defines a UML model and encodings consistent with the OGC Standards baseline to exchange and retrieve training data in the Web environment.

This document provides detailed metadata for formalizing the information model of training data. This includes, but is not limited to the following aspects:

— ~~—~~how the training data are prepared, such as provenance or quality;

— ~~—~~how to specify different metadata used for different ML tasks, such as scene/object/pixel levels;

— ~~—~~how to differentiate the high-level training data information model and extended information models specific to various ML applications;

— ~~—~~how to introduce external classification schemes and flexible means for representing ~~-~~labelling.

Geographic information — Training data markup language for artificial intelligence —

Part 1: Conceptual model

1 Scope

Within the context of training data for Earth Observation (EO) Artificial Intelligence Machine Learning (AI/ML), this document ~~defines~~specifies a conceptual model that:

- establishes a UML model with a target of maximizing the interoperability and usability of EO imagery training data;
- specifies different AI/ML tasks and labels in EO in terms of supervised learning, including scene level, object level and pixel level tasks;
- describes the permanent identifier, version, licence, training data size, measurement or imagery used for annotation;
- specifies a description of quality (e.g. training data errors, training data representativeness, quality measures) and ~~the~~ provenance (e.g. agents who perform the labelling, labelling procedure).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19101-1~~:2014~~, *Geographic information — Reference model — Part 1: Fundamentals*

ISO 19103~~:2024~~, *Geographic information — Conceptual schema language*

ISO 19115-1~~:2014~~, *Geographic information — Metadata — Part 1: Fundamentals*

ISO 19156~~:2023~~, *Geographic information — Observations, measurements and samples*

ISO 19157-1~~:2023~~, *Geographic information — Data quality — Part 1: General requirements*

3 Terms, definitions and abbreviated terms

~~3~~3.1 Terms and definitions

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

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

- ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp
- IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

~~3.1 Terms and definitions~~

3.1.1 ~~3.1.1~~
3D model reconstruction
<earth observation> task in which 3D objects and scenes are built from multi-view images

3.1.2 ~~3.1.2~~
artificial intelligence
AI
branch of computer science devoted to developing data processing systems that perform functions normally associated with human intelligence, such as reasoning, learning~~,~~ and self-improvement

[SOURCE: ISO/IEC 2382:2015, 2121393, modified — Notes 1 and 2 to entry have been removed.]

3.1.3 ~~3.1.3~~
change detection
<earth observation> recognition of changes between images acquired at different times

3.1.4 ~~3.1.4~~
class
<classification> result of a classification process as part of a classification system which subdivides concepts within a given topic area

[SOURCE: ISO 19144-2:2023, 3.1.6]

3.1.5 ~~3.1.5~~
dataset
identifiable collection of data

Note 1 to entry: A dataset can be a smaller grouping of data which, though limited by some constraint such as spatial extent or feature type, is located physically within a larger dataset. Theoretically, a dataset can be as small as a single feature or feature attribute contained within a larger dataset. A hardcopy map or chart can be considered a dataset.

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

3.1.6 ~~3.1.6~~
deep learning
DL
<artificial intelligence> approach to creating rich hierarchical representations through the training of neural networks with one or more hidden layers

Note 1 to entry: Deep learning uses multi-layered networks of simple computing units (or "neurons"). In these neural networks each unit combines a set of input values to produce an output value, which in turn is passed on to other neurons downstream.

[SOURCE: ISO/IEC TR 29119-11:2020, 3.1.26]

3.1.7 ~~3.1.7~~
generative model
<artificial intelligence> method of large model training, which improves model performance through unsupervised pre-training

Note 1 to entry: In the fine-tuning phase, labelled data ~~plays~~play a critical role in optimizing the model for specific vertical domains or tasks. By incorporating labelled data, the model can learn to accurately identify and extract relevant features, leading to better performance on specific downstream tasks. Overall, the combination of generative models and fine-tuning with labelled data can significantly improve the performance of large models in specialized domains or tasks.

3.1.8 ~~3.1.8~~
label
<earth observation> ~~refers to~~ known or expected results annotated as values of a dependent variable in training samples

Note 1 to entry: A training sample label is different from those on a geographical map, which are known as map labels or annotations.

3.1.9 ~~3.1.9~~
machine learning
ML
<artificial intelligence> process of optimizing model parameters through computational techniques, such that the model's behaviour reflects the data or experience

Note 1 to entry: ML processes create models from training data by using a set of learning algorithms, and then can use these models to make predictions. Depending on whether the training data include labels, the learning algorithms can be divided into supervised and unsupervised learning.

[SOURCE: ISO/IEC 22989:2022, 3.3.5, modified — Note 1 has been added.]

3.1.10 ~~3.1.10~~
object detection
<earth observation> recognition of objects from images

Note 1 to entry: The objects are often localized using bounding boxes.

3.1.11 ~~3.1.11~~
provenance
organization or individual that created, accumulated, maintained and used records

Note 1 to entry: In this document provenance is a record of how training data were prepared.

[SOURCE: ISO 19115-1:2014, 4.16, modified — ~~A new~~ Note 1 to entry ~~was~~has been added.]

3.1.12 ~~3.1.12~~
quality
degree to which a set of inherent characteristics of an object fulfils requirements

Note 1 to entry: Quality of training data (such as data imbalance and ~~mislabeling~~mislabelling) can impact the performance of artificial intelligence/machine learning (AI/ML) models.

[SOURCE: ISO 9000:2015, 3.6.2, modified — Notes 1 and 2 to entry have been ~~deleted~~removed, and a new Note 1 to entry has been added.]

3.1.13 ~~3.1.13~~
scene classification
<earth observation> task ~~to identify~~of identifying scene categories of images, on the basis of a training set of images whose scene categories are known

3.1.14 ~~3.1.14~~
semantic segmentation
<earth observation> task of assigning class labels to pixels of images or points of point clouds

3.1.15 ~~3.1.15~~
training dataset
<earth observation> collection of samples, often labelled with known or expected values for supervised learning

Note 1 to entry: A training dataset can be divided into training, validation~~,~~ and test sets. "Training samples" referred to in this document are different from "samples" referred to in ISO 19156~~:2023~~. They are often collected in purposive ways that deviate from purely probability sampling, with known or expected results labelled as values of a dependent variable for generating a trained predictive model.

3.2 Abbreviated terms

In this document, the following abbreviated terms and acronyms are used or introduced:

ATS	abstract test suite
DML	Data Markup Language
EO	earth observation
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
LC	land cover
LU	land use
OGC	Open Geospatial Consortium
RS	remote sensing
SAR	synthetic aperture radar
TD	training data
UML	Unified Modelling Language
URL	Uniform Resource Locator
URI	Uniform Resource Identifier
XML	Extensible Markup Language

4 Conventions

4.1 General

This clause provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

4.2 Identifiers

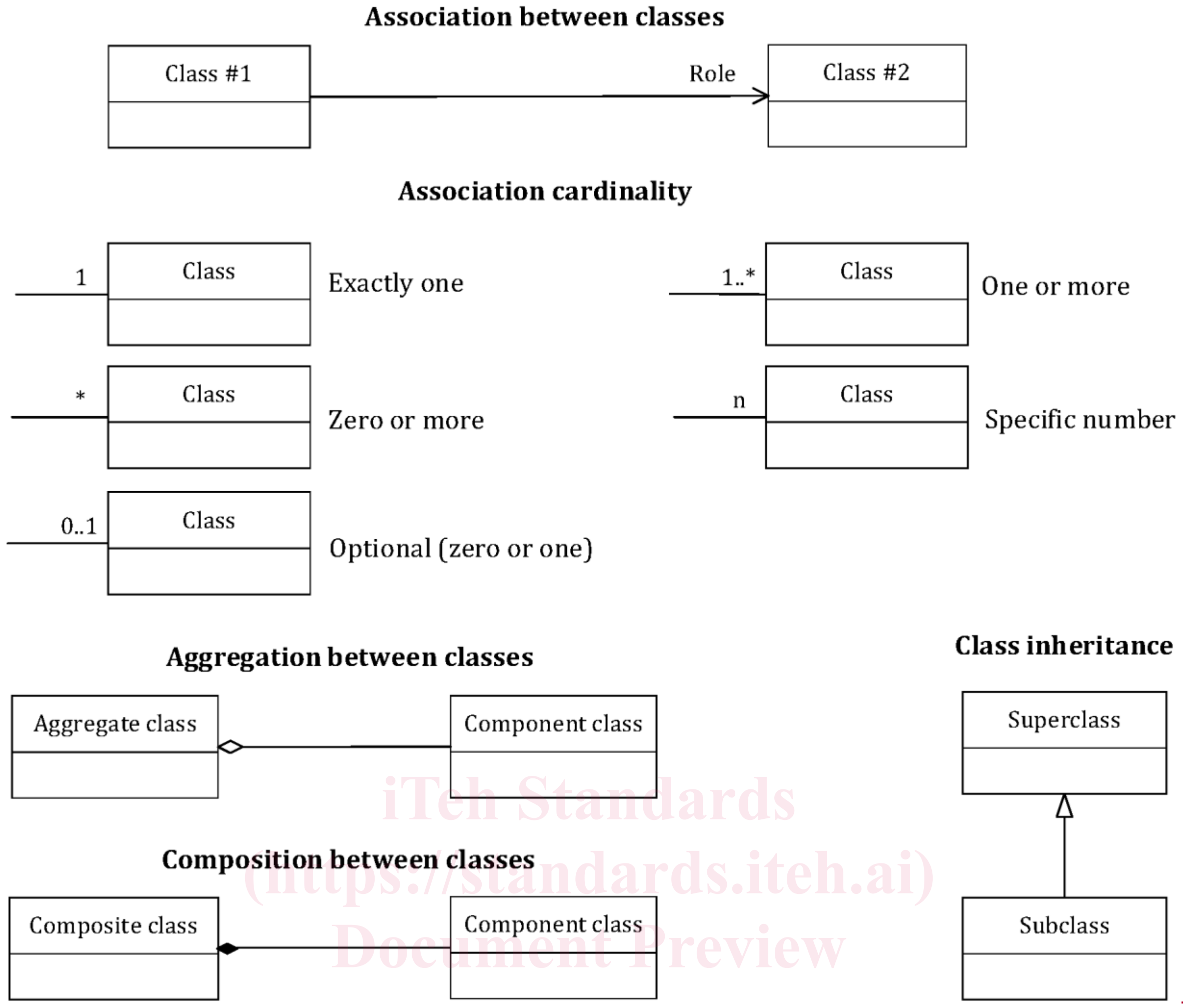
The ~~normative provisions~~requirements in this specification are denoted by the URI:

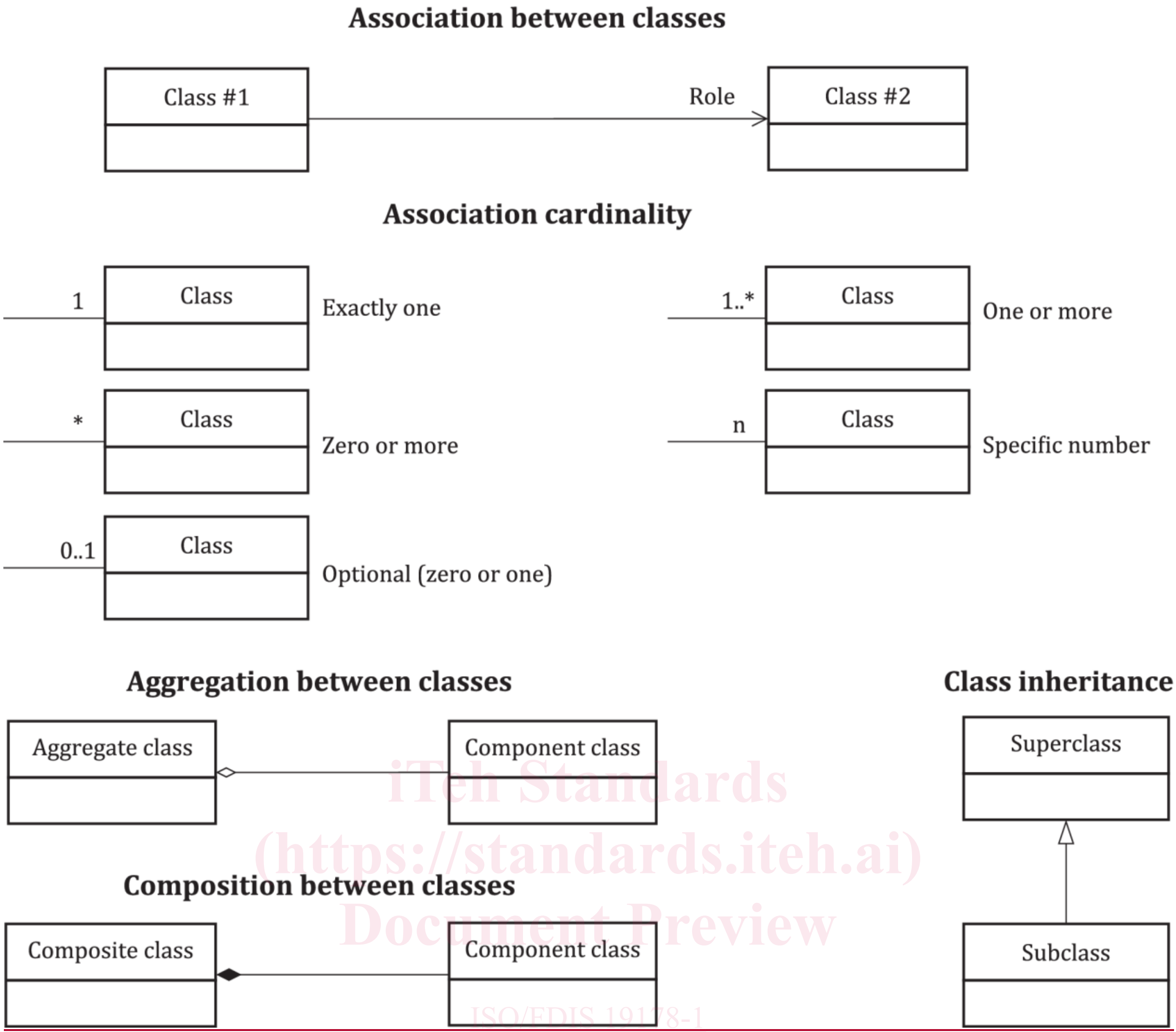
```
~~http~~http://www.opengis.net/spec/TrainingDML-AI-1/1.0
```

All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base.

4.3 UML notation

The conceptual model is presented in this document through diagrams using the Unified Modelling Language (UML) static structure diagram. The UML notations used in this document are described in the diagram in ~~Figure 1.~~Figure 1.


Association between classes
Class #1
Role
Class #2
Association cardinality
1
Class
Exactly one
1..*
Class
One or more
*
Class
Zero or more
n
Class
Specific number
0..1
Class
Optional (zero or one)
Aggregation between classes
Aggregate class
Component class
Class inheritance
Superclass
Subclass
Composition between classes
Composite class
Component class



NOTE For further information on the UML notation, see ISO 19103~~:2024~~.

Figure 1 — UML notation

All associations between model elements in the TrainingDML-AI conceptual model are uni-directional. Thus, associations in the model are navigable in only one direction. The direction of navigation is depicted by an arrowhead. In general, the context an element takes within the association is indicated by its role. The role is displayed near the target of the association. ~~If~~But, if the graphical representation is ambiguous~~ though~~, the position of the role has to be drawn to the element to which the association points~~ to~~.

The following stereotypes are used in this model.

— ~~—~~«DataType» defines a set of properties that lack identity. A data type is a classifier with no operations, whose primary purpose is to hold information.

— ~~—~~«CodeList» enumerates the valid attribute values. In contrast to Enumeration, the list of values is open and, thus, not given inline in the TrainingDML-AI UML Model. The allowed values can be provided within an external code list.

5 Conformance

This document defines a conceptual model that is independent of any encoding or formatting technologies. The standardization target for this document is:

— ~~—~~TrainingDML-AI conceptual model

Conformance with this document shall be checked using all the relevant tests specified in ~~Annex A~~Annex A of this document. The framework, concepts~~,~~ and methodology for testing, and the criteria to be achieved to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site~~ (Reference [10]).~~.[10]

All requirements-classes and conformance-classes described in this document are owned by the standard identified.

6 Overview

6.1 General

This document defines how to represent and exchange ML training data. The conceptual model includes the most relevant training data entities from datasets, to instances (i.e. individual training samples), to labels. The conceptual schema specifies how and into which parts ~~of~~ the training data should be decomposed and classified.

This document strategically addresses geospatial requirements by providing a modular and extensible framework tailored to EO applications. The content and format of training datasets differ depending on the EO ML scenarios they were collected for (e.g. scene/object/pixel levels). This document defines a UML model and encodings consistent with the OGC/ISO baseline standards to exchange and retrieve geospatial training data. ~~On the one hand, existing~~Existing geospatial standards (e.g.~~,~~, ISO 19101-1, ISO 19115-1, ISO 19157-1) can be reused when defining geospatial requirements on source RS images, label geometry, metadata~~,~~ and quality. ~~On the other hand, while~~While some general geospatial information such as the spatial extent and reference system information are defined for training data at the high level, other EO-specific information, such as the size of each sample image, spatial resolution, and bands, can be extended in a subclass at the low level. With a hierarchical and extensible structure, the training data model accommodates diverse geospatial data characteristics, ensuring flexibility and interoperability.

The training data model defined in this document facilitates interoperability by ~~allowing~~enabling heterogeneous training datasets to conform to a unified representation and exchange form. It ensures that training data from different vendors can be consistently shared and interpreted, improving the accessibility and promoting the integration of geospatial AI/ML resources.

The TrainingDML-AI conceptual model ~~(Clause 7)~~(Clause 7) is formally specified using UML class diagrams, complemented by a data dictionary ~~(Clause 8)~~(Clause 8) providing the definitions and explanations of the object classes and attributes. This conceptual model provides the basis for specifying encoding implemented in languages such as JSON, or XML. ~~Annex B~~Annex B provides a series of encoding examples, including representations for TrainingDataset, DataQuality, and TDChangeset encoding.

6.2 AI ~~Tasks~~tasks for EO

In recent years AI/ML has been increasingly used in the EO domain. The new AI/ML algorithms frequently require large training datasets as benchmarks. AI/ML TD have been used in many EO applications to calibrate the performance of AI/ML models. Many efforts have been made to produce training datasets to make accurate predictions. As a result, a number of training datasets are publicly available, with new datasets being constantly released. In the EO domain, examples of AI/ML training datasets have been developed in various tasks including the following typical scenarios~~:~~.

— ~~—~~Scene classification~~.~~: These algorithms determine image categories from numerous pictures (e.g. agricultural, forest~~,~~ and beach scenes). The training samples are a series of labelled pictures. The data can be either from satellite, drones~~,~~ or aircrafts. The metadata of the datasets often includes the number of training samples, the number of classes~~,~~ and the image size.

— ~~—~~Object detection~~.~~: These algorithms detect and localize different objects (e.g. airplanes, cars and ~~building~~buildings) in a single image. The image can be optical or non-optical, such as ~~Synthetic Aperture Radar~~synthetic aperture radar (SAR). Recent work also suggests an increasing focus on object detection from street view imagery. Objects can be labelled using either polygons or bounding boxes. The bounding boxes can ~~also~~ be either oriented vertically or ~~horizontal~~horizontally. The geometry of a bounding box can be expressed using top-left/bottom-right coordinates, coordinates of four corners, or centre coordinates along with the length and width of the box.

— ~~—~~Semantic segmentation~~.~~: In terms of ~~Land~~land cover (LC) and land use (LU) classification, this process assigns a LC/LU class label to a pixel (or groups of pixels) of RS imagery. ~~Considering~~In the context of semantic segmentation of 3D point clouds, it ~~is to classify~~classifies points of a 3D point cloud into categories. TDs are usually composed of RS images/point clouds, and the corresponding labelled value of each pixel/point recording its class.

— ~~—~~Change detection~~.~~: These algorithms identify the difference between images acquired over the same geographical area but taken at different times. The TD comprise a set of pre-change and post-change RS images, with the corresponding reference map labelled for changed and unchanged pixels. The image can be optical or SAR images.

— ~~—~~3D model reconstruction~~.~~: These algorithms infer the 3D geometry and structure of objects and scenes, mainly realized from the dense matching of multi-view images. The TD are usually composed of two-view or multi-view images, with the corresponding disparity map or depth maps as ~~ference~~reference data respectively.

6.3 Modularization

The TrainingDML-AI conceptual model provides models for the most important elements within TD. These elements have been identified to be either required or important in many different AI/ML tasks. However, implementations are not required to support the complete TrainingDML-AI model in order to be conformant to this document. Implementations may employ a subset of constructs according to their specific information needs. For this purpose, modularization is applied to the TrainingDML-AI model.

As shown in ~~Figure 2,~~Figure 2, the TrainingDML-AI conceptual model is thematically decomposed into a Basic module, a Provenance module, a Quality module and a Changeset module. The Basic module comprises the basic concepts and elements, including AI_TrainingDataset, AI_TrainingData, AI_Label~~,~~ and AI_Task, of the TrainingDML-AI, and thus, shall be implemented by any conformant system. The Provenance module provides a comprehensive definition of provenance by AI_Labeling, AI_Labeler~~,~~ and AI_Labeling Procedure. The Quality module offers quality description of TD with AI_DataQuality elements. ~~I~~The Changeset module defines AI_TDChangeset between versions of datasets.