

Standards for sensor orientation and sensor calibration
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1. Introduction

International standards in photogrammetry and remote sensing are demanded for many years, at least since the ISPRS congress in Amsterdam, 2000, where Ian Dowman called it a scandal that hardly anybody cared for that business.

In the meantime the ISO/TC 211 “Geographic information / geomatics” has completed a standard for sensor orientation. The development of two other standards makes good progress, the imagery reference model and the imagery metadata. An ISO standard on calibration has been discussed since 2003. However, the work has not yet started.

Though the ISO is the official standardization organization there are other bodies that are active in the standardization business such as the ISPRS, EuroSDR, CEOS, and the Open Geospatial Consortium (OGC). Their work has been integrated into the ISO developments through well formalized liaison relationships.

This paper deals only with mapping applications. Robotics are outside the scope.

2. Reference model and related ISO standards

All ISO standards for geographic information belong to *one* model that is written in the Unified Modelling Language. The layout of this model is described in the two standards ISO 19101 “Reference model” and the ISO 19101-2 “Reference model – Part 2: Imagery”.

Because in the beginning of its existence the ISO/TC 211 “Geographic information” assembled primarily expertise in vector-GIS the first generation of the ISO 19100 standards covered only the vector world. However, many of these standards have a generic meaning, in particular the ones on services (19119), metadata (19115), and quality (19113, 19114).

The ISO/TC 211 Working Group 6 “Imagery” was founded in order to develop the standards for the raster world. By now three standards are completed or almost

completed: The above mentioned ISO 19101-2, the ISO 19115-2 “Metadata – Part 2: Metadata for imagery and gridded data”, and the ISO 19130 “Sensor data models for imagery and gridded data”. Two further standards are planned, one on calibration and validation, another on encoding and data formats.

In the ISO raster data belong to the generic concept of coverage. A coverage is a two or three dimensional data set where each data contains one or many attributes. Examples for two dimensional coverages are a digital image or a digital elevation model. An example for a three dimensional coverage is a digital model of a water body with temperature information.

3. Sensor orientation

The elements of the ISO standards for sensor orientation are spread over a number of individual documents. The primary standard is the ISO 19130. The others are the ISO 19115 and the ISO 19115-2. According to the ISO 19119 “Services” the sensor orientation is a geographic spatial processing service.

3.1 ISO 19130

A photogrammetrist will be surprised by the structure of the ISO 19130. Within the document the well known concepts such as the interior and the exterior orientations are located in different sections. This unfamiliar picture is caused by a number of conditions that are typical of ISO standards. The documents integrate more than one technical domain and often the requirements exclude each other which lead to compromises that might technically not be the optimal solution. The standardization of ISO is a democratic process. Therefore any successful standard need to be accepted by a majority of the voting members of the Technical Committee.

The ISO 19130 standardizes the elements that are necessary to georeference geographic imagery. That imagery is two-fold as it may be photogrammetric or remotely sensed. The standard does not distinguish between film images and digital images, because the orientation data are alike within the scope of the standard. Though the 19100 series of standards are mainly concerned with digital data, the scanning of film images has been integrated because film is still very widely spread in practice.

Remote sensing systems appear in the ISO 19130 at various places. Originally the project team intended to make the standard as generic and as comprehensive as possible. The systems taken into consideration include the classical types of satellite sensors such as push-broom and whisk-broom as well as the new technologies such as lidar and radar. A new door was opened towards sound that is applied in sonar sensors used for hydrographical surveying.

During the development of the standard the involved parties made contributions with different technological depth. The push-broom and the whisk-broom model stayed as it had been proposed in the beginning. The lidar model received some good comments. The heavy input on the use of radar caused a lot of new text that partly changed the structure of the document. Sonar was rarely commented and therefore it stayed as a little section.

The ISO 19130 distinguishes between rigorous models and functional fit models. Rigorous models are based on the platform orientation and a sensor model. The exterior orientation always refers to the platform, even for photogrammetric purposes. In the case of a typical photogrammetric application the transformation between the platform and the sensor should be set to the unity matrix.

The exterior orientation contains the six parameters X_0 , Y_0 , Z_0 , ω , ϕ , and κ . Because the model also refers to satellite and military platforms it covers the description of velocity and acceleration.

The sensor model is manifold according to the above mentioned list. Film cameras and digital photogrammetric cameras are referred to as frame cameras. Their model includes the calibrated focal length, the principle point of symmetry, and the distortion parameters. The distortion model includes all relevant approaches.

The functional fit model is influenced by widely used processes of the remote sensing community and by works of the Open Geospatial Consortium. The model distinguishes between polynomials and ratios of polynomials. The latter has played a major role in the real-time control of vehicles.

A peculiarity of the ISO 19130 is the orientation-method using ground control points. This approach was introduced by a U.S. institution. Basically it means that not the transformation parameters are stored but the original observations – the GCP-coordinates and the related measurements.

The standard distinguishes between four types of GCP-cases. The GCP-survey has an identifier and two or three ground coordinates. The GCP-library has an identifier and two image coordinates. The GCP-location has two or three ground coordinates and two image coordinates. The GCP-registry has only an identifier in order to keep the ground coordinates secret.

Some applications require a partitioning of the entire model into submodels covering different areas of the image. This concept is called multimodel. An example of its application is the Replacement Sensor Model, an orientation method used in the U.S. military.

The name “raster digitised product” stands for scanned film and scanned paper maps. The ISO 19130 defines some related parameters, mainly the transformation.

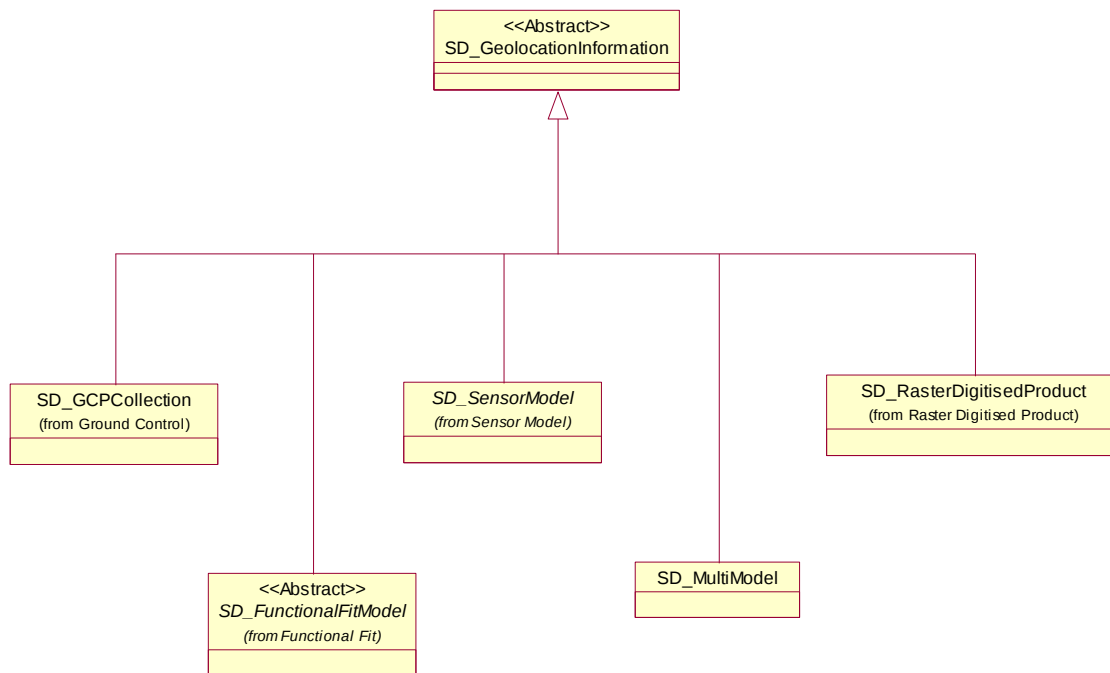


Figure 1: High-level model of geolocation information of ISO 19130

3.2 ISO 19115 and ISO 19115-2

The ISO 19115 “Metadata” contains only a few elements that are relevant for imagery. Examples are the availability-flags for orientation and calibration data.

The intention of the ISO 19115-2 “Metadata – Part 2: Metadata for imagery and gridded data” is a comprehensive list of possible metadata elements for imagery. The elements are grouped into the four packages content, data quality, acquisition, and spatial representation. Every package expands the equivalent package of the ISO 19115.

The content package contains descriptive and technical information of the data. The quality package includes a long list of quality elements and lineage. The quality elements are shown at figure 2. The lineage contains information about the history of the data, the algorithms used, and the processes performed. The spatial representation package distinguishes between georectified data, e.g. an orthophoto, and georeferenceable data, e.g. an aerial image with the exterior orientation known. The acquisition package contains information on instrument, operation, platform, objective, requirement, and plan.

Additional sections may come after the comment period on the first Committee Draft of ISO 19115 will have ended in February 2006.

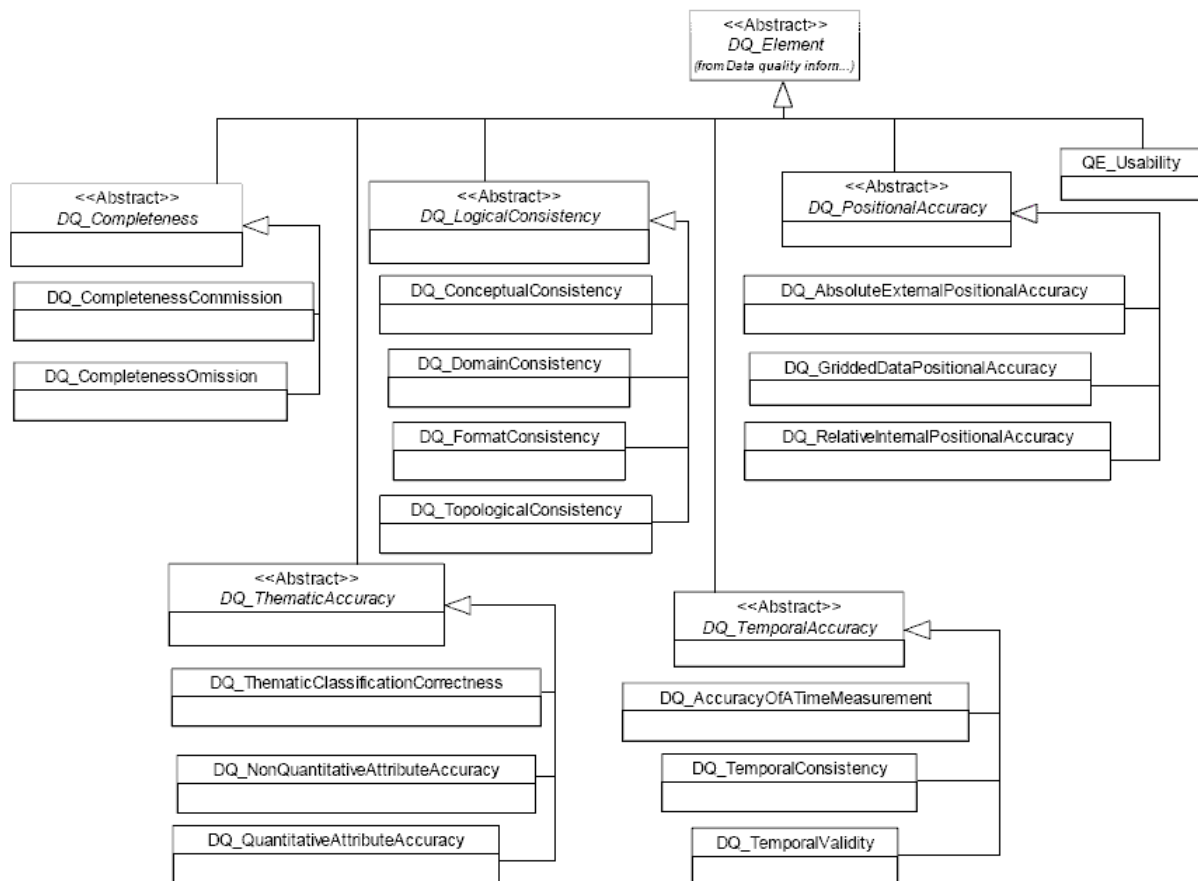


Figure 2: Data quality elements of ISO 19115-2

4. Sensor calibration

According to the ISO 19119 “Services” the sensor calibration is an information management service.

The start of the work on an ISO-standard for sensor calibration and validation has been discussed within the ISO/TC 211 for a while. The major initiative in this field was an ISPRS Workshop in 2003 that assembled a lot of the available expertise and perspectives. Still everybody feels that the topic might yet not be mature for standardization.

Independent of a global cautiousness some proposals were thrown into the discussion since 2003. During the ISPRS workshop in Gulfport two presentations gave a very detailed list of parameters that should become elements of an ISO standard. Their proposal might be a bit too detailed. However, they draw a typical picture of the requirements in practice. [Joseph 2004; Tansock Thurgood Larson 2004].

In Istanbul Liping Di described a general layout of a standard for calibration and validation. His proposal may be helpful as it is a generic approach [Di 2004].

Rainer Sandau’s proposal mainly deals with the measurable and relevant parameters of digital cameras [Sandau 2005].

Layout by Joseph, Tansock / Thurgood / Larson

Radiometric calibration

- radiometric response
- radiance calibration coefficients
- irradiance calibration coefficients
- response linearity
- array detector-to-detector response uniformity
- nominal detector id
- outlying detector id
- internal calibration resources

Spectral calibration

- relative normalization factor or scaling

Spatial calibration

- point / line response
- effective field of view
- modulation transfer function (MTF)
- field of regard
- distortion
- optical scatter

Temporal calibration

- repeatability
- amplitude response

Polarization calibration

- Mueller matrix coefficients or Stokes parameters
- S- and P-vectors
- degree of polarization
- angle of polarization

Layout by Di

Radiometrically uncalibrated data

- all necessary parameters required to derive physical values
- evaluate quality of measurements, e.g. system response, S/N

Radiometrically calibrated non-thematic data

- reporting methods used for calibration and correction
- reporting methods used for accuracy and precision

Layout by Sandau

Geometric calibration

- Principle point of autocollimation, calibrated focal length, radial distortion
- distortion coefficients according to D.C. Brown

Determination of the image quality

- detailed Modulation Transfer Function (MTF)

Radiometric calibration

- dark signal (DS)
- dark signal non-uniformity (DSNU)
- photo response non-uniformity (PRNU)
- spectral calibration
- polarization

5. Summary

The standardization work for imagery data is performed by the ISO/TC 211. Other organizations such as the ISPRS, EuroSDR, CEOS, and the OGC are also active and their contribution becomes part of the ISO developments. The sensor orientation standard has been completed. The comment period on the first Committee Draft of the imagery metadata standard ends in February 2006. An ISO standard on calibration and validation is planned, but has not yet started.

The activities of the EuroCOW are presently the most relevant contributions towards an international standard for calibration and validation.

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