INTERLIS 3 developments with 3D data types and better constraint support for 3D Cadastres

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SUMMARY

INTERLIS is an object relational modelling language and a Swiss national standard used to model and exchange cadastre data in a system neutral form. While INTERLIS was invented in Switzerland 30 years ago and used for over 25 years, in recent years the language has been applied also in many international projects founded by the Swiss government (ie. Azerbaijan, Belarus, Colombia, Georgia, Kosovo, etc.). One notable international development is the description of ISO 19152 LADM in the INTERLIS language, therefore enabling the use of all INTERLIS compatible tools (ie. UML/INTERLIS-Editor, compiler, data validation tools, data translation and schema generation) for LADM. The current version 2.4 of INTERLIS already supports geometric data types in 3D space (i.e. point, polyline, polygon). But for some future applications (i.e. 3D cadastres or BIM) some real 3D primitives (i.e. 3D volumetric type) and 3D constraints are still missing. Further, also topological structures for 2D and 3D space partitions are being investigated. For this reason it is planned to release a draft standard version of INTERLIS 3 which includes all missing types and functions by the end of 2018. INTERLIS 3 will also be proposed as an international standard. This paper describes the new features of the INTERLIS 3 language and how those new features can be applied to 3D cadastres, BIM and Smart Cities to solve real world problems.

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1. INTRODUCTION

The first version of the data modelling language INTERLIS was introduced in Switzerland in the late 1980s (Dorfschmid et al, 1987) and has become a Swiss standard in 1998 (SN 612030). The actual version 2.4 of the standard (eCH, 2016) is an object-oriented conceptual schema language (CSL), which is being used to precisely define (spatial) data models in textual form with a rigid computer process able syntax. An important characteristic of the language is that it can easily be understood by application and IT experts, thereby also bridging the gap between application and IT domains.

While INTERLIS was originally designed and used mainly for land administration, it is not restricted to land administration data modelling. In fact, INTERLIS is a general purpose modelling language. Due to its flexibility it has become part of the Swiss Act on Geoinformation (Swiss Confederation, 2007) and has been used to describe the 160+ data models of the Swiss National Data Infrastructure (NSDI).

Besides its use in Switzerland, INTERLIS has been applied with success in many international projects partially funded by the Swiss development aid (Azerbaijan, Belarus, Colombia (Jenni et al, 2017), Georgia, Kosovo, Serbia, etc.). Outside of Swiss development aid, projects in Greece (Kalogianni et al, 2016) and Turkey (Kara et al, 2018) have been started as well. We are therefore currently working on a draft version of INTERLIS 3, which will be proposed as an international standard.

This paper is structured as follows:

- In Chapter 2 we will present the current state of the existing INTERLIS 2 language, including applications and known limitations.
- In Chapter 3 some of the key elements of the proposed INTERLIS 3 language are discussed.
- In Chapter 4 the important new language elements are presented in more detail by examples.
- In Chapter 5 gives some overview on the activities going on to make INTERLIS 3 an international standard.
- In Chapter 6 we list the future work necessary to complete INTERLIS 3.

2. THE CURRENT STATE OF INTERLIS 2

2.1 Key Features

INTERLIS 2 is an object oriented data modelling / schema language on the conceptual level. To be a real conceptual modelling language it has to be system neutral. INTERLIS 2 also includes a system neutral data exchange mechanism based on XML. With INTERLIS 2 it is therefore possible to transfer whole datasets from one system (i.e. LIS/GIS) to another system (i.e. database) without information loss, thereby making free system choice a reality (freedom of system choice in Swiss Geoinformation Act [3]).

2.2 Data types

INTERLIS 2 has a rich set of data types directly build into the language. The primitive types are: Integer, Double, String, Boolean and Geometry (see below). From primitive types it is possible to declare new types by restriction or to form complex types from primitive types with structures, bags and lists.

2.3 Geometry

It is one of the notable features of the INTERLIS language to include geometry types (Point, Line and Surface) directly in the language, making INTERLIS especially useful to describe GIS / LIS systems. When INTERLIS was invented in the late 1980's, full 3D-support was not an urgent issue in cadastral surveying at that time. While it was necessary to store points and lines in 3D space for fixed points and utility services, real 3D primitives, such as solid's have only gained more interest in the recent years (3D cadastres, BIM). So it is some kind of "natural" that a language this age has no full 3D support (yet).

2.4 Constraints

Since the early 1990 with the introduction of the first official surveying model (AV93) there has always been a strong focus on quality control in INTERLIS applications. The system neutral INTERLIS exchange format made it possible to develop system independent tools (INTERLIS Checker), to automatically control the quality of datasets. So it comes at no surprise, that also the language fully supports the definition of constraints.

2.5 Tool Support

The following list gives a brief overview by naming some of the most important tools (free and commercial):

- The INTERLIS compiler checks the syntactical correctness of an INTERLIS data model (free);
- The INTERLIS checker can quality check INTERLIS XML data against INTERLIS data models (free and commercial);
- The INTERLIS UML editor is used to create INTERLIS models from UML diagrams or to visualize existing INTERLIS data models as UML diagrams (free);
- Data translators can convert data sets from many GIS systems / databases to and from INTERLIS XML (free and commercial);
- Schema tools can generate database schemata directly from INTERLIS data models (free and commercial);

More information about the INTERLIS 2 language and its tools is available at the official INTERLIS web site at www.interlis.ch.

2.6 Applications

In many countries the provision of spatial data in a non-proprietary format and in a documented data model is quite challenging. In Switzerland the situation is much less critical: Since starting the initiative for the reformation of cadastral surveying in the Mid-Eighties INTERLIS provided the standard for describing and interchanging spatial data. The early commencement of standardisation of spatial data in Switzerland was a pre-requisite for building up spatial data infrastructures and support the fast technical implementation of Web-Services and Open Government Data portals.

By being able to describe both data and model, each dataset being exchange can be automatically checked for logical consistency. This ensures that only consistent records are retrieved. Several hundred datasets are exchanged and checked between systems daily. Nowadays for a large amount of spatial datasets the data model is documented using INTERLIS and the data can be retreived as INTERLIS exchange files. In addition to the cadastral data worth around 3.5 billion Swiss Francs, additional datasets with a similar value are modeled and exchanged using INTERLIS. The two main benefits from the application point of view are therefore quality assurance and cost reduction: the system-neutral exchange eliminates the close connection to a system manufacturer, as all objects and relationships can be output to the interface.

2.7 Limitations

While INTERLIS 2 has undeniable strengths, like every other standard it has also has its weaknesses. The most limiting factor is lack of an International Standard (IS). The lack of an IS prevented or delayed the use of INTERLIS in international and large national projects. Even in Switzerland it is much more time consuming to convince decision makers to rely on INTERLIS, while there are similar IS available (i.e. UML or GML). We therefore strongly hope that INTERLIS 3 can be established as an IS in the near future (see Chapter 5 for more details).

Technically the lack of proper 3D types is limiting the use of INTERLIS 2 in the context 3D cadastres, BIM or Smart Cities. This weakness will be addressed in INTERLIS 3.

An open point is also the lack of topological structures for 2D / 3D as in ISO 19107 (Geographic Information-Spatial Schema). But this has to be discussed in the INTERLIS 3 working group in more detail.

The last well known limitation is the relatively small number of INTERLIS solution providers. Most of them are based in Switzerland. But with INTERLIS as an IS, the situation should improve in the future.

3. NEW FEATURES IN INTERLIS 3

3.1 New 3D Geometry Types

While 3D support in INTERLIS 2 is limited, INTERLIS 3 will have full 3D support. As the main extension the SOLID type will be introduced in INTERLIS 3. A SOLID is defined as follows:

> "A SOLID is a collection of three or more (planar) surfaces (outer boundary) and zero to many inner boundaries (inclusions) that do not touch the outer boundary. All limiting surfaces are oriented counter clockwise, with the normal vector pointing to the outside of the SOLID surfaces. Surfaces of a SOLID may not overlap and may have no gaps.", see also (Kazar et al, 2008).

Below is an example of a SOLID in INTERLIS 3:

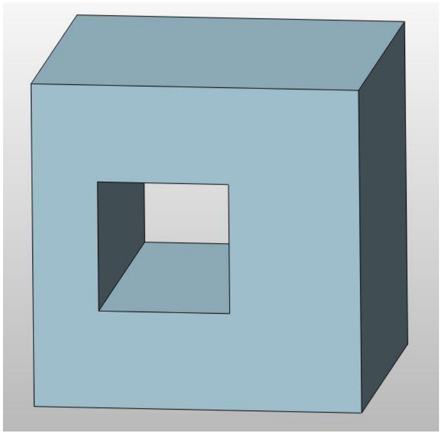

Figure 1.Solid with (straights) vertex coord3d

The SOLID above consist of a single outer boundary. Note: even if the figure above has a hole, it has no inner boundaries (inclusions). Inner boundaries are inside the outer boundary and do not touch the outer boundary.

3.2 2D and 3D Space Partitions

In INTERLIS 2 we already know the 2D space partition type AREA. AREA is a SURFACE collection, where no SURFACE's in the collection can overlap. The same concept will be introduced for SOLID's in 3D. A VOLUME_PARTITION is a collection of SOLID's where no SOLID's in the collection can intersect each other. The spatial constraints that hold for AREA and VOLUME_PARTITION can be exploited in data exchange to transfer only the limiting edges or faces between two objects.

3.3 New 3D Constraint Functions

To formulate meaningful constraints in 3D, INTERLIS 3 will included an extended set of constraint functions. Notable examples of 3D capable constraint functions are: intersect() returning a Boolean value and distance() returning a Double value. With intersect() it is possible to require by negation, that no SOLIDS intersects another SOLID or 3D object whereas distance() allows to define a minimal distance between objects (see also examples in next section).

4. SOME INTERLIS 3 EXAMPLES

4.1 Modelling a simple 3D Volume Object

The first INTERLIS 3 example is a very simple class with a SOLID geometry:

```
CLASS Object_3D =
   kind: MANDATORY (kind1, kind2, kind3);
   geometry: MANDADTORY SOLID;
END Object_3D;
```

Instances of Object_3D have a single SOLID as geometry and a single non geometric attribute kind. Note: It is possible for a class to have more than one geometric attribute (2D and/or 3D).

The following listing shows the XML-encoding of a unit cube in INTERLIS 3 (XML-headers are not displayed):

```
<INTERLIS3.Examples.Object_3D TID="1">
  <kind>kind1</kind>
  <geometry>
    <SURFACE>
      <BOUNDARY>
        <POLYLINE>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
          <COORD><C1>1.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
          <COORD><C1>1.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
        </POLYLINE>
      </BOUNDARY>
    </SURFACE>
    <SURFACE>
      <BOUNDARY>
        <POLYLINE>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
          <COORD><C1>1.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
          <COORD><C1>1.0</C1><C2>1.0</C2><C3>1.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>1.0</C2><C3>1.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
        </POLYLINE>
      </BOUNDARY>
    </SURFACE>
    <SURFACE>
      <BOUNDARY>
        <POLYLINE>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>1.0</C2><C3>1.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
          <COORD><C1>0.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
        </POLYLINE>
      </BOUNDARY>
    </SURFACE>
```

```
      <SURFACE>
        <BOUNDARY>
          <POLYLINE>
            <COORD><C1>1.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>1.0</C2><C3>1.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
          </POLYLINE>
        </BOUNDARY>
      </SURFACE>
      <SURFACE>
        <BOUNDARY>
          <POLYLINE>
            <COORD><C1>0.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
            <COORD><C1>0.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>0.0</C2><C3>1.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
            <COORD><C1>0.0</C1><C2>0.0</C2><C3>0.0</C3></COORD>
          </POLYLINE>
        </BOUNDARY>
      </SURFACE>
      <SURFACE>
        <BOUNDARY>
          <POLYLINE>
            <COORD><C1>0.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
            <COORD><C1>1.0</C1><C2>1.0</C2><C3>1.0</C3></COORD>
            <COORD><C1>0.0</C1><C2>1.0</C2><C3>1.0</C3></COORD>
            <COORD><C1>0.0</C1><C2>1.0</C2><C3>0.0</C3></COORD>
          </POLYLINE>
        </BOUNDARY>
      </SURFACE>
    </geometry>
  </INTERLIS3.Examples.Object_3D>
```

As INTERLIS 3 is not ready for production yet, the SOLID example can be realized in INTERLIS 2 as follows:

```
GM_Curve3D = POLYLINE WITH (STRAIGHTS)
   VERTEX HKoord WITHOUT OVERLAPS > 0.001;

STRUCTURE GM_Surface3DListValue =
   value: MANDATORY GM_Curve3D;
END GM_Surface3DListValue;

STRUCTURE GM_Solid =
   geometry: LIST {3..*} OF GM_Surface3DListValue;
END GM_Solid;

CLASS Object_3D =
   kind: MANDATORY (kind1, kind2, kind3);
   geometry: MANDADTORY GM_Solid;
END Object_3D;
```

Because the SOLID is not directly available in INTERLIS 2 the SOLID was implemented in INTERLIS 2 as Type GM_Solid. The domain definitions (in red) have been taken from (Kalogianni et al, 2017).

4.2 Using Constraints on 2D / 3D Objects

A simple constraint example are buildings that should not be closer than 3 meters to the outer boundary of a parcel. This can be modelled with the distance2d() function as follows:

```
CLASS Parcel =
   geometry: AREA WITH (STRAIGHTS) VERTEX Coord2d;
END Parcel;

CLASS Building =
   geometry: SURFACEPATCH WITH (STRAIGHTS) VERTEX Coord3d;
MANDATORY CONSTRAINT
   distance2d(geometry,edges(Parcel,geometry)) >= 3.0;
END Building;
```

Note: We have used the function distance2d() instead of distance(), as the distance should be measured only in the 2D projection. The function edges() delivers all edges of an AREA as a list of POLYLINE's.

5. INTERNATIONAL STANDARDIZATION

While INTERLIS is available since many years, it is still a Swiss National Standard. This fact has been limiting its use in international and even large national projects. It is therefore our goal to establish INTERLIS as an international standard. The first step in this direction was the creation of the INTERLIS manifesto (Kaufmann et al, 2018) in, which has been signed by over 40 supporters from 9 nations. Next step is to create a draft of the INTERLIS 3 language by end of September 2018. This draft will be made available to the INTERLIS community for commenting. The final draft will be used as input for international standardization. It is difficult to predict how much time it will take to make INTERLIS an international standard, but it is reasonable to expect a final standard in 2019.

Recently, INTERLIS has been used in combination with ISO 19152:2012, the Land Administration Domain Model (LADM). LADM country profiles have been developed in INTERLIS for countries such as Switzerland, Colombia, Greece and Turkey. The motivation is the complementary nature of INTERLIS and LADM. The conceptual model of LADM is described in UML class diagrams, but still quite far from implementation. By expressing LADM and the country profiles in INTERLIS the gap towards implementation is reduced. Specifically, the possibility to express (spatial) constraints is very important for including more formal semantics in the model, which is later on used to make sure data quality is maintained. Within ISO active standards are periodically revised, and after six years also LADM will be revised. Therefore in 2017 and 2018 two international FIG LADM workshops have been organized (Lemmen at al 2018) to discuss the scope and content of revision. During the 2018 workshop an international group of experts advised (LADM, 2018): 'Make a stable & complete schema in INTERLIS version 2 for use in the annex which includes the imported schemas from other ISO standards eg ISO19107 (.ili) The use of constraints should be emphasized (and perhaps constraints should be more formal in LADM core; e.g. UML/OCL)'. This advice was included in the New Work Item Proposal (NWIP) that was submitted in May 2018 by FIG to ISO TC211 for the revision of LADM. The NWIP also includes other main extensions such as valuation information, marine cadastres, links to physical/building models, spatial planning/zoning legal spaces, more formal semantics (both in legal and spatial side), 3D spatial profiles, aggregated land indicators (in context of the SDGs), standardized workflows (process models), and to close the gap toward implementation multiple encoding of the LADM technical model are proposed: BIM/IFC, CityGML/InfraGML, RDF, GeoJSON and as indicated above also INTERLIS. Given the extend of the revision, and the ISO procedures to develop standards it is expected that this revision will take 4 years, and that by 2022 the LADM v2 will be available, most likely as a multi-part standard. Currently, INTERLIS is not an international standard, which is not per se a must for being used in an ISO standard. However, it would be a big benefit if INTERLIS itself was also an international standard.

6. FUTURE WORK

INTERLIS 3 is still a work in progress; the final draft will be completed by end of 2018. Work items discussed in the working group are:

- New curves in 2D space (clothoid, spline);
- Curved surfaces in 3D space (NURBS);
- Non 2 manifolds.
- SOLID definition by translation or rotation of 2D curves, i.e. the rotation of a circle around an axis to form a torus;
- SOLID definition by CSG (Constructive Solid Geometry), i.e. adding or subtracting SOLID's to form a new SOLID;
- 2D/3D topological structures;
- Robust set of 2D and 3D constraint functions;

Note: The above list is neither complete nor is it sure that the mentioned items make it to the final draft. But it is our intention to discuss INTERLIS 3 as broad as possible to open up even more application domains for INTERLIS 3 in the future (i.e. CAD/CAM like settings).

To integrate 3D in INTERLIS the current INTERLIS 2.4 reference manual has to be reworked. This major revision will also be used to tighten the manual and make it more accessible for readers. While the original version of the INTERLIS 2.4 reference manual is written in German and then translated to English, the INTERLIS 3 reference manual will be written in English directly.
It should not be forgotten, that the existing INTERLIS 2 tools have to be adapted to support the new INTERLIS 3 features. This may take some time, but the benefits are worth waiting for.

7. CONCLUSIONS

By improving INTERLIS by 3D geometry types and 3D constraints, INTERLIS can be used more easily in the context of 3D Cadastres, BIM or Smart Cities.
The upcoming standardization of INTERLIS on an international level could boost the interest in INTERLIS and therefore produce better data models, easier data exchange and more free and commercial tools in the future.

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BIOGRAPHICAL NOTES

Michael Germann is co-founder and CEO of infoGrips LTD, Zürich Switzerland. In 1988, he received a master's degree in computer science from ETH Zürich. His main interests are software development, data modelling, data quality control and the implementation of spatial data infrastructures. He worked in international World Bank projects (Azerbaidjan, Colombia) as a consultant and on several Swiss standards including INTERLIS. He was also part-time member of the Swiss delegation at ISO TC211.

Jürg Lüthy is member of the Management Board at Acht Grad Ost AG, one of the largest geomatics companies in Switzerland. He obtained a master's degree in 1996 from Federal Institute of Technology Zurich (Switzerland) in Rural Engineering and Survey. From the same institution he holds a PhD (2007). He has many years of experience in spatial data management, transition from paper maps to data centric systems and the operation of Spatial Data Infrastructures. His current focus lies in the provision of holistic information using modern web-technologies like designing information management platforms or building the technical infrastructure for Cadastre of Public-law Restrictions on landownership. He is the Swiss delegate to FIG Commission 3. Since 2016 he is president of SLM Swiss Landmanagement Foundation.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology, and head of the 'GIS Technology' Section, Department OTB, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres'.

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