InfraGML – current status, implementations and future development

Inframodel Workshop
Helsinki, Finland
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It all started with LandXML

- LandXML specifies an XML file format for civil engineering design and survey measurement data.
- The primary goals for providing a standard data format are:
  - Data exchange between software applications
  - Long-term data archival
- Volunteer organizations and individuals have contributed to the development of LandXML via LandXML.org
- The LandXML community consisted of over 650 organizations with 750 members in over 40 countries and there were over 70 registered software products that supported LandXML as of 2009.
- But then LandXML fell upon hard times and the OGC was approached to assume maintenance of the schema.
Land and Infrastructure (LandInfra)

• The Land and Infrastructure Conceptual Model Standard (LandInfra)
  – It’s all about the land upon which infrastructure facilities are built
  – and the infrastructure facility improvements themselves
  – including the surveying necessary for the construction and recording of the facilities and land interests

• “use case driven subset of LandXML functionality, but that is implemented with the OGC Geography Markup Language (GML) and supported by a UML (Unified Modeling Language) conceptual model”

• LandInfra is the conceptual model, specified as a proposed OGC Standard following ISO and OGC Topics (example. 1 / 2 / 19 & 20)

• An InfraGML encoding standard followed in 8 Parts
LandInfra / InfraGML
http://www.opengeospatial.org/standards/landinfra

- Land Features
- Roads
- Railway
- Core
- Survey
- Facilities
- Alignment
- Projects
- Land Division
- Condominiums
LandInfra / InfraGML Structure

- Split in 7 Parts (containing all 14 InfraGML Requirement Classes matching LandInfra RCs)
- Each part have its own (standard) document
- Encoding & Application could choose which parts it will support (with involving dependencies)
As promised, here I send you some information about the Norwegian standardization project (2019/2020) that is partially based on LandInfra

- Link to UML (see also screenshot in the pptx): http://gml.arkitektum.no/BA_nettv_2017/NorskInfraGML/NorskInfraGML_20190306/HTML-dokumentasjon/index.htm - this is from the pilot project in 2018 but at the same time the starting point for the standardization project recently started
- Please find attached a pptx with basic information about the standardization project
- I send a copy from an email that I sent to Scott Simmons last year related to the question if what we did in the pilot project was in accordance with the OGC policies (turned out it was).
Norway example

The intention is to have a data model based on existing standards. For that purpose the project started implementing parts of LandInfra and InfraGML. However, the content of LandInfra/InfraGML addresses only some of the use cases of the project and one started to extend the content of LandInfra/InfraGML where necessary.

Extensions exist on two levels:

Conceptual level (UML)
Encoding level (GML)
Conceptual level (UML)

- All modeling work is based on UML that has been reverse-engineered from official xsd files and UML-diagrams in the documents on: http://www.opengeospatial.org/standards/infragml.
- Extensions of the content in UML-elements are done using generalization.
- The introduced subtypes of LandInfra classes are within new packages defined in the project while the original supertypes are within the OGC/LandInfra package.
- No changes are made to the original LandInfra elements.
- All introduced changes are at a subtype level within packages and namespaces that differ from the LandInfra ones.
Encoding level (GML)

• Only for the Norwegian extensions new GML schemas have been created. These schemas have their own namespaces (different from LandInfra). Also, they have import statements with references to the official OGC InfraGML schemas and their namespaces, as shown in the example below. These references have been added manually to the schemas that have been derived automatically from the UML.

```xml
<include schemaLocation="NorsInfraGML_e.xsd"/>
<import namespace="http://www.opengis.net/gml/3.2" schemaLocation="http://schemas.opengis.net/gml/3.2.1/gml.xsd"/>
<import namespace="http://www.opengis.net/infraGML/alignment/1.0" schemaLocation="http://schemas.opengis.net/infraGML/part3/1.0/alignment.xsd"/>

<element name="Senterlinje" type="InfraN.SenterlinjeType" substitutionGroup="lia:Alignment">
  <annotation>
    <documentation>
      XSD_redigering: Erstatte substitutionGroup="veg.Alignment" med substitutionGroup="lia:Alignment"
    </documentation>
  </annotation>
</element>
<complexType name="SenterlinjeType">
  <complexContent>
    <sequence>
      <extension base="lia:AlignmentType"/>
    </sequence>
  </complexContent>
</complexType>
```

• References to concrete elements defined in the OGC InfraGML schemas are done in e.g. substitutionGroup ("lia:Alignment") and extension base statements ("lia:AlignmentType") as shown below.
Utfordringene med InfraGML som gjorde at vi måtte lage vår egen «profil»

- Ønsker «norsk vegbyggings-metode» dekket
- vil ha mer kontroll på validering av geometri
- behov for utvidet prosjekt-modell, og problemer med obligatoriske, engelsk-baserte kodelister spesielt for RoadElementType.

The challenges with InfraGML that made us have to create our own «profile»

- Want «Norwegian road design method» covered
- Want more control over the validation of geometry
- Need for extended project model,
- and problems with mandatory English-based code lists, especially for RoadElementType.

- Two videos in Norwegian
  https://youtu.be/R8neFZqJl5c
  https://youtu.be/obLi0CObr1g
Some Use Cases

- Interchange data through the complete live cycle of Infrastructure Facility

Digital Construction

Building Information Modelling (BIM) is applied at every stage of the construction and infrastructure process.

1. Surveying/Reality Capture
2. Planning, Concept, 3D Design & Pre-Construction
3. Setting Out, Site Layout
4. Siteworks/Earthworks & Grading
5. Utility
6. Construction
7. Construction Validation
8. Connecting Infrastructure
9. Facilities Management
10. Completion & Handover
11. Structural Monitoring

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Where does LandInfra fit in?

LandInfra is a connecting bridge between IFC and CityGML, but is conceptually, semantically, and geometrically closer to CityGML.

The LandInfra standard and its role in solving the BIM-GIS quagmire
IDBE – OGC/bSI Collaboration WG
(Integrated Digital Built Environment)

New Collaboration strategy and MOU launched in 2-day Workshop in Nov 2016
Interoperability needs alignment of Standards
Interoperability needs alignment of Standards
# Comparison CityGML, IFC and LandInfra

## Table 1: A comparison of CityGML, IFC and LandInfra

<table>
<thead>
<tr>
<th>#</th>
<th>Criterion</th>
<th>CityGML</th>
<th>LandInfra</th>
<th>IFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body</td>
<td>OGC</td>
<td>OGC</td>
<td>buildingSMART</td>
</tr>
<tr>
<td>2</td>
<td>Version</td>
<td>2.0.0</td>
<td>1.0.0</td>
<td>IFC4 Addendum 2</td>
</tr>
<tr>
<td>3</td>
<td>Users</td>
<td>3D city modellers</td>
<td>Survey engineers &amp; BIM</td>
<td>BIM &amp; AEC (Architecture, Engineering &amp; Construction)</td>
</tr>
<tr>
<td>4</td>
<td>Encoding</td>
<td>GML</td>
<td>GML</td>
<td>Mainly STEP (Standard for the Exchange of Product model data)</td>
</tr>
<tr>
<td>5</td>
<td>Focus</td>
<td>City objects</td>
<td>Land and infrastructure</td>
<td>BIM models</td>
</tr>
<tr>
<td>6</td>
<td>Geometry</td>
<td>Subset of ISO 19107 / GML 3.1.1</td>
<td>ISO 19107 + more</td>
<td>ISO 10303</td>
</tr>
<tr>
<td>7</td>
<td>Topology</td>
<td>Shared surfaces only</td>
<td>Between facility parts</td>
<td>Openings, coverings and other connections</td>
</tr>
<tr>
<td>8</td>
<td>Semantics</td>
<td>Detailed</td>
<td>Not so detailed</td>
<td>Detailed</td>
</tr>
<tr>
<td>9</td>
<td>Metadata</td>
<td>Basic</td>
<td>ISO 19115 compliant</td>
<td>Extensively but inconsistently used</td>
</tr>
<tr>
<td>10</td>
<td>LODs</td>
<td>5 different LODs</td>
<td>Not supported</td>
<td>Not supported</td>
</tr>
<tr>
<td>11</td>
<td>Extensions</td>
<td>Generics or ADEs</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>12</td>
<td>Appearance</td>
<td>Supported</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td>13</td>
<td>Software support</td>
<td>Low</td>
<td>Almost nonexistent</td>
<td>Medium</td>
</tr>
<tr>
<td>14</td>
<td>Codelists</td>
<td>Supported with ISO 19103</td>
<td>Supported with ISO 19103</td>
<td>Enumerations only</td>
</tr>
<tr>
<td>15</td>
<td>Land use</td>
<td>Simple types</td>
<td>Complex LADM types [26]</td>
<td>Not relevant</td>
</tr>
<tr>
<td>16</td>
<td>File size</td>
<td>Large [35]</td>
<td>Large</td>
<td>Very large</td>
</tr>
</tbody>
</table>
Use IFC the right way!

Use IFC as intended
- Exchange and share BIM Models!
- No replacement of own software format
- Handle change management by BCF
Background - Basic conceptual breakdown IFC

Spatial structure
- A unique hierarchical spatial breakdown of the project
- Each component belongs uniquely to one element in this breakdown

Component structure
- Hierarchical composition of physical parts
- Each part belongs directly or indirectly to an element in the spatial structure

Functional structure
- Grouping of physical parts, composed for a common purpose or function or to provide a service
- A physical part may belong to many functional elements

This structure has governed the layout of the structure for the IFC Road conceptual model.
Background - Basic conceptual breakdown
OGC LandInfra - Road

LandInfraDataset
  ▪ Header information about a dataset
    ▪ E.g. defaultCRS

Project structure
  ▪ A hierarchical breakdown of a project
  ▪ Each project part relates to facility parts and represents some work (design, construction, maintenance etc) for that part of a facility

Facility structure
  ▪ A hierarchical breakdown of a facility
  ▪ A facility has a life cycle

PhysicalElement structure
  ▪ Hierarchical composition of physical parts
  ▪ Each part belongs directly or indirectly to a facility part

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Introduction to examples on the coming slides

• Used IFC Road conceptual model instantiation examples
• Tried to represent the same structure using OGC LandInfra (InfraGML) concepts
• FacilityPart and RoadElement in InfraGML allows for user defined typing
  • This is used in the examples for cases where certain IFC Road types did not exist in InfraGML, e.g. Segment, Intersection…
• Relationships between FacilityParts in InfraGML can be typed using character string values
  • This is used to represent relationships from IFC Road such as “Passes over” etc e.g. a Road segment passes over or under a Bridge
• Project and Facility has slightly different semantics in IFC vs InfraGML
  • Project in IFC is the top node in any exchange
  • In InfraGML a LandInfraDataset may contain both projects and facilities where a facility has its own lifecycle and the project (which may be linked to facilities) represents the actual work (design, construction, …)
  • Project instances was omitted in the examples but could be added
• Suitable spatial representations in InfraGML could be further investigated
• Cross sectioned representations in InfraGML was not considered in these examples
Breakdown example when roads crossing at grade – IFC Road
Breakdown example when roads crossing at grade - InfraGML
Breakdown example when roads crossing without junction – IFC Road
Breakdown example when roads crossing without junction - InfraGML

LandInfraDataset

Facility → Facility

FacilityPart

Road ID=A 101

alignment

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

Road ID=A 1

alignment

FacilityPart type=bridge

relationship(passesOver)

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

FacilityPart type=SEGMENT

Alignment

Alignment

A 101

A 1

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Breakdown proposal example for railway crossing at grade – IFC Road

- IFCProject
  - IfcRelAggregates
  - IfcSite
    - IfcRelAggregates
      - IfcAlignment
        - IfcRelAggregates
          - IfcRoad
            - Name=A101
            - PredefinedType=HIGHWAY
          - IfcRelAggregates
            - IfcRoadPart
              - PredefinedType=SEGMENT
            - IfcRelAggregates
              - IfcRoadPart
                - PredefinedType=RAILWAYCROSSING
            - IfcRelAggregates
              - IfcRoadPart
                - PredefinedType=SEGMENT
      - IfcRelAggregates
        - IfcRailway
          - IfcRelAggregates
            - IfcRailwayPart
              - PredefinedType=ROADCROSSING
          - IfcRelAggregates
            - IfcPavement
              - IfcRelAggregates
                - IfcPavement
                - IfcRelAggregates
                  - IfcPavement
                  - IfcRelAggregates
                    - IfcPavement

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Breakdown proposal example for railway crossing at grade - InfraGML
Superelevation example – IFC Road

LandInfraDataset
IfcRelAggregates
Facility
IfcRelAggregates
Road
IfcRelAggregates
FacilityPart
type=someurl#SEGMENT
IfcRelAggregates
FacilityPart
type=someurl#TRAFFICLANE
IfcRelAggregates
IfcReLContainedIn
SpatialStructure
Alignment
Axis
IfcAlignmentCurve
IfcLDistanceExpression
IfcSuperelevationEvent
Side=RIGHT
SuperElevation=0.
Transition=LINEAR
IfcReLContainedIn
SpatialStructure
IfcWidthEvent
Side=RIGHT
Transition=CONST
Width=3500.
Superelevation example - InfraGML

SuperElevation is not part of InfraGML – Road at this moment
- Linear events is part of GML 3.3
- IFC Road uses containment by Spatial structure element to connect the event with the appropriate element.
- Similar issue for InfraGML when added – how to define which part e.g. SuperElevation relates to?
Pavement example using surface representation for each layer – IFC Road

IfcAlignment
  ↓
IfcAlignmentCurve
    ↓
IfcAlignmentCurve
      ↓ BasisCurve
      ↑ OffsetValues
IfcOffsetCurve
  ↓
IfcDistanceExpression
  ↓
IfcOpenCrossProfileDefinition
  ↓
IfcSectionedSurface
  ↓
IfcShapeRepresentation
  ↓
IfcProductDefinitionShape
  ↓
IfcPavement
  ↓ RelAggregates
  ← RelAssociatesMaterial
IfcMaterial
  ↓
IfcMaterial
  ↓

IfcDistanceExpression
  ↓
IfcOpenCrossProfileDefinition
  ↓
IfcSectionedSurface
  ↓
IfcShapeRepresentation
  ↓
IfcProductDefinitionShape
  ↓
IfcPavement

IfcDistanceExpression
  ↓
IfcOpenCrossProfileDefinition
  ↓
IfcSectionedSurface
  ↓
IfcShapeRepresentation
  ↓
IfcProductDefinitionShape
  ↓
IfcPavement

IfcMaterial

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Pavement example using surface representation for each layer - InfraGML

No SectionedSurface type exists in GML!

There is also Road.surface and Road.surfaceSet
• However, in this example we attach geometry on RoadElement level
Pavement example using stringline representation for each layer – IFC Road

IfcAlignment
  - Axis
  - IfcAlignmentCurve

IfcAlignmentCurve
  - Tag=CT
  - BasisCurve
  - IfcOffsetCurveByDistances
    - Tag=LT
    - OffsetValues
      - IfcDistanceExpression
        - DistanceAlong=0.
        - OffsetLateral=-3.
        - OffsetVertical=-0.1

IfcProductDefinitionShape
  - IfcShapeRepresentation
    - IfcAlignmentCurve
      - Tag=CT
      - BasisCurve
      - IfcOffsetCurvByDistances
        - Tag=LT
        - OffsetValues
          - IfcDistanceExpression
            - DistanceAlong=0.
            - OffsetLateral=3.
            - OffsetVertical=-0.1

IfcGeometricCurveSet
  - IfcAlignmentCurve
  - Elements

IfcMaterial
  - IfcPavement
    - PredefinedType=BASECOURSE
  - RelAssociatesMaterial
  - RelAggregates

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Pavement example using stringline representation for each layer - InfraGML

There is also Road.stringLine and Road.stringLineSet
- However, in this example we attach geometry on RoadElement level
Earthworks example according to IFC Road proposal

- **IfcProject**
- **IfcSite**
  - **IfcRelContainedInSpatialStructure**
  - **IfcRelAggregates**
  - **IfcRoad**
    - **IfcRelContainedInSpatialStructure**
    - **IfcRelAggregates**
      - **IfcRoadPart**
        - **IfcRelContainedInSpatialStructure**
        - **IfcRelAggregates**
          - **IfcEarthworksElement**
            - **IfcCourse**
              - **IfcErosionPrevention**
              - **IfcCourse**
                - **IfcExcavation**
                  - **IfcGeographicElement**
                    - **IfcRelVoidsElement**

- **Existing Ground**
- **Excavation Cut**
- **Pavement**
- **Road formation level**
- **Subgrade bed fill**
- **Subgrade embankment fill**
- **Reinforced soil**
- **Slope fill**

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Earthworks example according to IFC Road proposal - InfraGML

- **LandInfraDataset**
  - **landFeature**
    - **Facility**
      - **Road**
        - Name = vt12
      - **Alignment**
    - **FacilityPart**
      - type = SEGMENT
        - **RoadElement**
          - type = SUBGRADE
          - **RoadElement**
            - type = SLOPEFILL
        - **RoadElement**
          - type = CAPPING_LAYER
        - **RoadElement**
          - type = BASECOURESE
        - **RoadElement**
          - type = REGULATINGCOURSE
        - **RoadElement**
          - type = PAVING
        - **RoadElement**
          - type = GROUTED
        - **RoadElement**
          - type = PLANTING
    - **RoadElement**
      - type = CUT
    - **RoadElement**
      - type = PAVING
    - **RoadElement**
      - type = CUT

- **FeatureAssociation**
  - **toFeature**
    - **toRole** = voided
  - **fromFeature**
    - **fromRole** = voids
  - **RoadElement**
    - type = CUT

- **Existing Ground**
  - **Excavation**
    - **Cut**
      - **Pavement**
        - **Subgrade**
          - **Foundation**
  - **Reinforced soil**
  - **Slope fill**
  - **Subgrade bed fill**
  - **Road formation level**

- **LandSurface**

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Data sources: What is relevant?

- GDB/MXD
- SHP
- WM(T)S
- HxIP
- ESRI/Google Maps
- WFS
- KML/KMZ
- XML
- CityGML
- InfraGML
- LADM
- IFC / BCF
- DWG/DXF
- DGN
- PDF
- STEP/IGES
- E57
- LAS
- PTS
- LGS
- Fieldbooks
- PDF
- ...