FME, BIM & CityGML

CityGML Workshop:
Revit BIM model conversion to CityGML Using FME

January 16th 2014
Agenda

CityGML Overview
- FME & 3D: concepts and formats
- CityGML characteristics, structure and zoom levels

FME & CityGML
- Reading / Writing
- Workflows
- Courthouse Demo: Revit to CityGML conversion

Challenges, considerations, resources

FME & XML, FME Server, & web services
FME Capabilities

Transform Data to Use and Share

- **Convert** spatial data between hundreds of formats
- **Transform** spatial data into the precise data model you need
- **Integrate** multiple different data types into a single data model
- **Share** spatial data with people where, when and how they need it
FME supports reading from a wide array of data formats and types

- 300+ formats, with more added each year
- CAD, GIS, raster, database, web, non-spatial, 3D
Transformation

- Move data between formats and systems
- Restructure data models and schemas
  - Geometry
  - Attributes
  - Coordinate systems and projections
- Example
  - Derive new attribute values or construct geometry
New to FME?

- Getting started page:
  
  http://fme.ly/GetStarted

- Attend a weekly FME Desktop overview webinar:
  
  http://fme.ly/WeeklyIntro
Current FME 3D Formats

3dPDF, CityGML, OBJ, IFC, SketchUp, LandXML, Shape, OracleSpatial, Collada, DWG, DGN, OpenFlight, Direct3D, VRML, Geodatabase, 3ds, XML
3D Formats

- Adobe 3D PDF
- LAS / LAZ
- Autodesk 3ds
- AutoCAD Civil 3D
- AutoCAD DWG/DXF/RealDWG
- Bentley Microstation
- CityGML 2.0, ADEs
- COLLADA
- DirectX X File
- Esri ArcGIS Layer
- Esri Geodatabase
- Free File Geodatabase API
- NetCDF
- Esri Shape
- Google SketchUp, KML
- IFC
- LandXML
- Oracle Spatial Object
- Oracle Spatial Point Cloud
- Point Cloud XYZ
- Pointools POD
- Presagis Openflight
- VRML
- Wavefront OBJ
- XML / GML
FME Tools for Tackling 3D

- Format translation
- Database loading and extraction
- GML, XML and web service support
- Schema mapping
- Geometry model conversion (e.g. solid to mesh)
- Geometry transformation
- Geometry validation
- Complex geometry support, hierarchical
- Reprojection, geo-referencing, vertical datums
Turn This...
...Into This
IFC: Industry Foundation Classes
WHAT IS A POINT CLOUD. WHAT IS LIDAR

Dmitri's Point Cloud Lab (Table of Contents)

Next Article:
Point Cloud in FME 2011: Scenario Driven Development

With FME 2011, we added a new type of geometry called Point Cloud.

Wikipedia defines a point cloud as a set of vertices in a three-dimensional coordinate system.

We can think about a point cloud as a collection of multiple points, however, that would be oversimplifying things. Surprisingly, when lots of points are brought together into a single feature, they start to show some new qualities.
Texture placement
CityGML: Motivation

- An increasing number of cities and companies are building virtual 3D city models
- Different application areas:
  - E.g. Urban planning, disaster management, navigation, environmental simulations
- Graphical or geometric models are limited to visualisation purposes
- Growing need for Semantic Models to satisfy:
  - thematic queries, analysis, spatial data mining
  - Reusability -> costs reduction
CityGML: Motivation
CityGML: What is it?

- CityGML is a data model and exchange format for virtual 3d city models
- Modeling of all relevant parts of the virtual city according to their semantics, geometry, topology and appearance
- GML 3 application schema (XML based)
- CityGML 1.0 is OGC Standard since 2008
- Latest version is 2.0 approved in spring 2012
CityGML | Characteristics

- Modularisation (Thematic Model)
  - Buildings, Roads, CityFurniture,...
- Coherence of semantics and geometry
  - Explicit relations between semantic objects and their geometrical representation (B-Rep)

(C) by T.H. Kolbe
CityGML | Characteristics

- Multi-Scale Modelling [Level of Detail]
  - From landscape to interior model

- LOD 0 – Regional model
- LOD 1 – City model
- LOD 2 – City model with roof structure
- LOD 3 – Detailed architecture
- LOD 4 – Interior Model

Source: slide from: Christian Dahmen, conterra
CityGML | Characteristics

- External References
  - Refer to external data sources containing additional data

- Appearance (Textures)

- Application Domain Extensions (ADE)
  - E.g. NoiseADE

- Generic city objects and attributes

Source: slide from: Christian Dahmen, conterra
Thematic modules

Vegetation
CityObjectGroup
WaterBody
CityFurniture
Relief
Tunnel
Building
Bridge
Transportation

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FME's support for CityGML

- **Read and Write CityGML up to version 2.0**
  - CityGML v0.4, v1.0
- **Support for any arbitrary ADE’s (new)**
  - E.g. INSPIRE, Dutch IMGeo, Noise
- **FME supports**
  - All thematic modules
  - Level of Detail (LoD 0-4)
  - Generic objects and attributes
  - Non-spatial data / metadata
  - Reprojection
FME Support for CityGML
FME Support for CityGML
<citymodel>
  <cityObjectMember>
    <Building gml:id="104167">
      <gml:name>A house</gml:name>
      <boundedBy>
        <GroundSurface gml:id="8b7970ee">
          <lod2MultiSurface>
            <gml:Polygon>
              <gml:exterior>
                <gml:LinearRing>
                  <gml:posList>3477350.98 5551112.32 ...</gml:posList>
                </gml:LinearRing>
              </gml:exterior>
            </gml:Polygon>
          </lod2MultiSurface>
        </GroundSurface>
      </boundedBy>
      <boundedBy>
        <RoofSurface gml:id="fme-gen-4c">
          ...
        </RoofSurface>
      </boundedBy>
    </Building>
  </cityObjectMember>
</citymodel>
Comparison: Sketchup - Simple
Comparison: IFC - Complex
Comparison: CityGML – Just Right
Reading CityGML

- **Parameters**
  - Reader Driven by CityGML Schema
  - Additional ADE Schema File(s)
  - Ignore xsi:schemaLocation
  - Include Only Feature Types in Dataset
Reading CityGML

- One FME Feature Type per CityGML class (object)
Reading CityGML

- Building in LoD 1, 2, and 3

LoD 1
- 1 Building

LoD 2
- 1 Building
- 4 WallSurfaces
- 2 RoofSurfaces
- 1 GroundSurface

LoD 3
- 1 Building
- 4 WallSurfaces
- 2 RoofSurfaces
- 1 GroundSurface
- 2 Door
- 11 Window

© KIT – Karlsruher Institute of Technology
Riverside Building: LOD2
Riverside Building: LOD3
Bridge LOD1

© 3D Pilot NL data, www.geonovum.nl/3d
Bridge: LOD3

© 3D Pilot NL data, www.geonovum.nl/3d
Typical CityGML Workflows

- Data Inspection and Evaluation
- CityGML model generation
- Creating LODs
- 3D data generation from 2D
  - 2.5D draping
  - 3D extrusion
- Database loading
- BIM to GIS
- Export to client formats (PDF / KML)
Key Transformers for 3D

- 3DAffiner
- 3DArcReplacer
- 3DPointAdder
- **AppearanceAdder, AppearanceStyler**
- Clipper
- CSGBuilder / CSGEvaluator
- **Extruder**
- FaceReplacer
- **GeometryCoercer**
- GeometryExtractor
- GeometryReplacer
- GeometryColorSetter
- **GeometryFilter**
- GeometryValidator
- MeshMerger
- Orienter
- PointCloudCoercer, PointCloudSplitter
- SurfaceReverser
- **SurfaceModeller**
- Triangulator
Writing CityGML

Requirements

- Good knowledge of CityGML specification, especially the UML models
- CityGML specification document - www.opengeospatial.org/standards/citygml
- Knowledge of how to adopt UML models to FME Workbench
- CityGML Readers / Writers & Tutorial
Prepare your source data

Add CityGML specific attributes and geometry properties
- Format Attribute `citygml_lod_name`

Build relationship between features
- Example: 'Building' address 'Address'
- Use `gml_id` and `gml_parent_id` for relation
- Format Attribute `citygml_feature_role`

CityGML Model entities by FME feature types
- Manually define or import CityGML entities
- Import entities from an existing CityGML dataset
CityGML: Important notes

- **Use exact naming and word spelling for**
  - Feature Types: Building ≠ building ≠ BuildinG
  - Attribute names: citygml_lod_name ≠ citygmlIlodname
  - Attribute values: boundedBy ≠ Boundedby
  - Geometry properties: lod1Solid not LOD1solid

- **Always refer to CityGML specification**

- **Key Transformers**
  - AttributeCreator, AttributeRenamer
  - GeometryPropertySetter (alias GeometryTraitSetter)
  - 3DForcer, Extruder, GeometryCoercer
<CityModel>
    <cityObjectMember>
        <bldg:Building gml:id="UUID_13d7d225">
            ...  
            <creationDate>2008-12-09</creationDate>
        </bldg:Building>
        <bldg:boundedBy>
            <bldg:WallSurface gml:id="UUID_50d7d286">
                ...  
            </bldg:WallSurface>
            <bldg:opening>
                <bldg:Window gml:id="UUID_86e6b220">
                    ...  
                </bldg:Window>
            </bldg:opening>
            <bldg:RoofSurface gml:id="UUID_535118a1">
                ...  
            </bldg:RoofSurface>
            <bldg:GroundSurface gml:id="UUID_5350147b">
                ...  
            </bldg:GroundSurface>
        </bldg:boundedBy>
    </cityObjectMember>
</CityModel>
Example CityGML Workspace

- Building with Wall- and RoofSurface
BIM to GIS example: IFC to CityGML

- Geometry model differences
  - CSG vs vector feature based
- Data model differences
  - object vs relational
- Data model gaps
  - Elements in one not in the other
- Lack of widespread industry and toolset support
- Massive datasets
### IFC to CityGML: Schema Mapping challenge

<table>
<thead>
<tr>
<th>IFC</th>
<th>UBM</th>
<th>CityGML</th>
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</thead>
<tbody>
<tr>
<td>IfcBuilding</td>
<td>UBMBuilding</td>
<td>AbstractBuilding</td>
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<td>IfcBuildingStorey</td>
<td>UBMSpace</td>
<td>BoundarySurface</td>
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<tr>
<td></td>
<td></td>
<td>- RoofSurface</td>
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<td>- WallSurface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- GroundSurface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- and other building elements</td>
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<tr>
<td>IfcSpace</td>
<td>UBMSpace</td>
<td>Room</td>
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<tr>
<td></td>
<td>- UBMOpenedSpace</td>
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<td>- UBMClosedSpace</td>
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<td>UBMLLevel</td>
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<td>FloorSurface</td>
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<td>- (Floor Slab)</td>
<td>CeilingSurface</td>
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<td></td>
<td>- (Ceiling Slab)</td>
<td>RoofSurface</td>
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<tr>
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<td>InteriorWallSurface</td>
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<td>- UBMInteriorWall</td>
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<tr>
<td>IfcOpeningElement</td>
<td>UBMOpening</td>
<td>WallSurface</td>
</tr>
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<td></td>
<td>- IfcDoor</td>
<td>Opening</td>
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<tr>
<td></td>
<td>- IfcWindow</td>
<td>- Door</td>
</tr>
<tr>
<td>IfcBeam</td>
<td>UBMBuildingInstallation</td>
<td>BuildingInstallation</td>
</tr>
<tr>
<td>IfcColumn</td>
<td>UBMBuildingInstallation</td>
<td>BuildingInstallation</td>
</tr>
<tr>
<td>IfcCovering</td>
<td>UBMBuildingInstallation</td>
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<td>UBMBuildingInstallation</td>
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</tr>
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<td>IfcRamp</td>
<td>UBMBuildingInstallation</td>
<td>BuildingInstallation</td>
</tr>
</tbody>
</table>
IFC to CityGML: Geometry mapping challenge

Differing Modeling Paradigms

**BIM (e.g., IFC)**
Constructive Solid Geometry

**3D GIS (e.g., CityGML)**
Boundary Representation

- **Volumetric, parametric primitives representing the structural components of buildings**
- **Accumulation of observable surfaces of topographic features**

Source: slide from: Thomas H. Kolbe – joint work with Claus Nagel & Alexandra Stadler
IFC to CityGML Workflow

- Read IFC
- Geometry coercion solid to surface (convert CSG geometries to B-rep geometries).
- Relationship resolution
- Schema mapping IFC to CityGML feature types and fields
- ID generation, LODs, format attributes
- CityGML object construction
- Validation
- Geo-referencing
- Write CityGML
IFC to CityGML Workspace

Geometry coercion, schema mapping and geo-referencing
IFC to CityGML Result
Revit to CityGML: Leesburg Courthouse Square

1. Courthouse BIM created in **Revit** by **DBI Architects**
2. Revit Extension - **FME Exporter** - creates .rvz file
3. **FME Workspace**: Revit .rvz to CityGML conversion
4. **VirtualCitySystems** imports CityGML into their 3D City Database
Revit to CityGML Demo: FME Workspace

- Read Revit .rvz file
- Revit to CityGML feature type mapping
  - FlowTerminal + Railing => IntBuildingInstallation
- Aggregate to combine features
  - Rebuild Stair and Window structure
- Set CityGML LOD and Role
  - Space: lod4MultiSurface, InteriorRoom
- Reprojection to EPSG:26918
- Scaler to convert height in feet to meters
- Write CityGML features
  - Write Name, ObjectType, Tag attributes
Revit to CityGML Workspace pt A
Key Transformers

direction: geometry extraction
CityGML Writing Transformers

filtering, id generation, configuring geometry model
Revit to CityGML Demo: Leesburg Courthouse Square Result
Leesburg Courthouse Square: Window Object Selection
Real World CityGML Models

- EU INSPIRE ADE
- Netherlands IMGeo 3D ADE, Geonovum
- Environmental Noise Directive
- 3DCityDB, Berlin
- Karlsruhe, Zurich, Nuremberg
CityGML has strongly influenced the INSPIRE BU model - based on City GML v2.0

Differences:
- INSPIRE names for attributes common to other themes (ids, time)
- part can’t have parts
- appearances simplified
- fields added to support INSPIRE requirements (environmental policy)
INSPIRE ADE for CityGML

- Application domain extensions (ADEs) extend CityGML with additional fields and feature types.
- CityGML ADE **BuildingsCore3D_ADE.xsd** is an alternative encoding for **Buildings3D** and adds fields needed for INSPIRE (core3d_*)
- Produced by teams at TU Munich and University of Bonn.
- Extended 3D ADE (BuildingsExtended3D) coming soon.
3D Netherlands: 3D Pilot NL
IMGeo basemap from 2D to 3D

Safe Software Involvement

- BIM to GIS alignment (IFC to CityGML)
  - Provide tools but not the alignment design
- Geometry Validation
  - currently sponsoring the open source effort
- CityGML data management, updates
- 3D CityGML data generation and enrichment from 2D

www.geonovum.nl/3d
Input: 2D IMGeo (3D Pilot NL)
Output: 3D IMGeo (3D Pilot NL)
2D to 3D Workflow

1. Read 2D CityGML with IMGeo ADE schema
2. Read DTM and DSM (or LIDAR)
3. Build surface model from DTM or LIDAR
4. Drape 2d features on surface
5. For 3d, extract max building height from DSM
6. Extrude from surface to height, coerce to solid
7. Set required citygml format attributes (citygml_lod_name etc) & desired styling
8. Write to CityGML (IMGeo ADE schema)
2D to 3D Generation Workspace

SurfaceDraper, GeometryPropertySetter, FeatureTypeFiltering, GeometryColorSetter
Results: 3D PDF
EU Environmental Noise Directive 2002

3D geodata in CityGML as input for the calculation of noise immersion maps

Noise immersion maps reported to EU (via WMS service)
<core:cityObjectMember>
  <fn:CityFurniture gml:id="CFUR_0815">
    <fn:function>1520</fn:function>
    <fn:lod1Geometry>..
    <noise:noiseCityFurnitureSegmentProperty>
      <noise:NoiseCityFurnitureSegment gml:id="CFRS_0815">
        <noise:type>1</noise:type>
        <noise:reflection>absorbierende Lärmschutzwand</noise:reflection>
        <noise:reflectionCorrection uom="dB">4.123</noise:reflectionCorrection>
        <noise:height uom="m">7.123</noise:height>
        <noise:distance uom="m">21.123</noise:distance>
        <noise:lod0BaseLine>
            <gml:coordinates decimal="." cs="," ts="">5707335,2524175,188 5707338,2524181,188 5707330,2524185,188 5707327,2524179,188</gml:coordinates>
          </gml:LineString>
        </noise:lod0BaseLine>
      </noise:NoiseCityFurnitureSegment>
      <noise:noiseCityFurnitureSegmentProperty>
    </noise:NoiseCityFurnitureSegmentProperty>
  </fn:CityFurniture>
</core:cityObjectMember>
Example - 3D City Model of Berlin

580,000 buildings, reconstructed from 2D-cadastre and LIDAR-data

Textures automatically extracted from oblique aerial images

Semantic information based an cadastre data

www.3d-stadtmodell-berlin.de
Repository for the official 3D city model
- Complete representation of topography and landscape
- Data from various sources (cadastre, planning, architecture, utility networks, etc.)

Usage of 3D city model for applications like
- City and Urban Planning
- Political Issues and Consulting, Civic Participation

Basis for the Berlin 3D Spatial Data Infrastructure
- Access through standardized OGC Web Services, Google Earth (KML), online streaming

3DCityDB v2 is a free and open source 3D database
- to store, represent, and manage virtual 3D city models

www.3dcitydb.org
3D City Model for Karlsruhe, Germany

City of Karlsruhe, real estate office

Facts
- 296,000 inhabitants
- 173 km² land area
- 85,000 buildings

Components of the 3D city model
- Terrain Model (1m) + uses
- Building model LOD 1
- Building model with detailed roofs and fototexturing for selected buildings (LOD 2)
- Building LoD 3 (~ 50 landmarks)
- City furniture
- Bridges

Quelle: Stadt Karlsruhe, Liegenschaftsamt
3D City Model for Zurich, Switzerland

City of Zurich, Surveying Geomatics

Facts

- 370,000 inhabitants
- 92km² total, of which 52 km² built-up area
- Terrain of 370m to 1000m elevation
- 55,000 buildings, 40,000 properties

Product offering

- Digital terrain model (LOD 0)
- 3D block model (LOD 1)
- 3D roof model (LOD 2)
City of Nuremberg
Additional 3D Topics / New In FME

- Geometry validation, repair
- Analysis (VolumeCalculator)
- Data distribution (web formats)
- FME Improvements:
  - Smarter geometry conversion (GeometryCoercer, GeometryRefiner)
  - Point cloud processing (PointCloudExpressionEvaluator)
  - Vertical datum support
  - Performance
3D GeometryValidator

- Checks for solids with inverted faces, dangling surfaces, unsealed solids, etc.
- Flag errors with meaningful attributes and geometric locations of the errors.
- Repair option for 3D surfaces and solids.
GeometryValidator Transformer

Set of Issues to Detect:
- Surfaces and Solids
- Custom
- All
- None
- OGC

Basic Geometry Integrity
- Contains NaNs or Infinities
- Contains Null Geometry
- Duplicate Consecutive Points
- Degenerate or Corrupt Geometries
- Self-Intersections in 2D
- Missing Vertex Normals
- Non-Planar Surfaces
- Invalid Solid Boundaries
- Invalid Solid Voids
- Fails OGC Simple
- Fails OGC Valid
- Missing Texture Coordinates

Detected Issue List Name: issues

Attempt Repair: Yes

OK
Cancel
3D Validation - Detection
3D Validation - Repair
Volume Transformer: Geometry Filter XQuery

GQuery
internal geometry queries based on XQuery
Value added processing: Compute load risk

Based on slope and area
FME Server Data Distribution: 3DPDF, KML/COLLADA
Skape: 3D City Model Distribution

View, manipulate and export pre-built 3D city models, 2D mapping and terrain anywhere in Great Britain

- View spot height data, 3D terrain and aerial photography in any location free of charge
- Import your CAD designs into a real 3D environment
- Export cost effective pre-built 3D building and terrain data to use within your existing CAD software
- View and capture the visual impact of your imported buildings from unlimited vantage points
- Apply sun lighting to see where your building shadows fall any time of day or year
- Instantly create and export 3D model fly-throughs, 3D PDFs, 3D prints and screenshots
- Free registration | Pay as you go | Open data licenses

Register For Free Now

Buy 2D, Get 3D Free!

Purchase OS MasterMap 2D DXF...
Skape: Westminster Abbey view, manipulate and export 3D cityscapes
CityGML Challenges

- 2D vs 3D
- Spatial reference systems
- Model vs generic inputs
- Attribute schema limitations (list structures etc)
- Geometry model differences
- Resolving / maintaining xlink references
- Texturing
- Massive datasets (XML files vs databases)
- Lack of widespread industry, toolset and viewer support
FME Support for XML: Overview

- Support for XML family of formats
- XML reading and writing
- GML reading and writing (application schema)
- CityGML (as already covered)
- XML processing including XQuery, XSLT, validation and formatting
- XML writing with XMLTemplater
- Web Services hosted by FME Server
XML Reading

- **XML format family**: more than 37 predefined formats supported including: KML, GML, Open Street Map, GPX, LandXML, TigerGML, INSPIRE ...

- Read virtually any XML document using **XML reader’s** element matching in **Feature Path mode** (e.g. metadata)

- Read **GML with application schema**

- Read **CityGML** with optional **ADE** schema
**XML Processing**

- Use **flattening** to resolve objects into features and fields
- Use **schema mapping** transformers to relate flattened fields to desired destination data model
- OR preserve XML data model and update in place using **XQuery** and XSLT transformers
- **Validate** XML for syntax or against application schema
- **Format XML** to serialize or pretty print
XML Writing

- Write with one of FME’s 20+ predefined XML writers.
- Use FME’s new GML writer to write to virtually any valid, user supplied application schema.
- Use XMLTemplater to merge FME attributes into an XML template or structure you define. Supports sub-templates to nest feature types.
Key points on new FME GML Writer

- GML writing uses application schema (.xsd’s) - destination model captured from the application schema
- Map schema directly to destination feature type fields
- Multiple, complex geometry support
- Geometry names and traits
- Voidable attributes in output GML / null support in FME
- XMLTemplater no longer needed for GML writing, but useful for other XML generation like metadata
What is FME Server?

- Share the power of FME across the enterprise.
  - **Use** the same FME Engine that powers FME Desktop
  - **Transform & Share** spatial data via web services
  - **Author** on FME Desktop, publish to FME Server as web service – no code
What FME Server can do for you

- Data Distribution
  - Data Download Service
- Live Data Streams
  - Data Streaming Service
- Upload and Validation
  - Data Upload Service
- Centralize Data Transformation
  - Job Submitter Service
- Other Services
  - Scheduling Service
  - Notification Services
  - OGC Services
Why FME Server?

- You need to **distribute** data to your team, your organization, contractors, public, regulators etc.

- You need to **process** a lot of data on a **schedule**

- You need users to **upload** data and you need to ensure it’s **valid** and matches your format and data model

- You need to get or send **live data** for decision makers
Publishing Web Services: Workspace as Service Broker

Not only can FME stream XML data
Now FME can handle client / server communications

- Each client request just another workspace input that generates an XML response
- E.g getCapabilities, describeFeature, getFeature
- Can support virtually any XML or JSON based web service (Atom, OGC WFS, WCS, SOS, etc)
- Supports GET or POST
- FME can publish virtually any complex XML format via web services (INSPIRE, AIXM, CityGML, metadata)
FME Workspace as Web Service Broker

GetCapabilities Request → Response XML

GetFeature Request → Response GML

FME WxS Workspace

FME Server
FME and XML: Highlights

- **Consume XML** – Leverage existing XML content and services using FME’s XML & GML readers

- **Schema Transformation** – easily integrate complex XML data models with existing relational GIS systems

- **Generating XML** – XML & GML writers, XMLTemplater, validation and formatting make XML generation a breeze

- **Automate** XML processing workflows

- **Web services** – publish services using FME workspaces as web service brokers via **FMEServer** – no code!
Summary

- **CityGML** - Ideal for 3D modeling and data exchange
- **FME** – Ideal tool to support reading & writing CityGML with translation and transformation abilities
- FME powered the transformation from Revit to CityGML for the **Court House** demo
- FME Supports
  - Versions up to **CityGML 2.0**
  - all **levels of detail** and thematic modules
  - **generic objects** and attributes any arbitrary **ADE**
- FME offers many tools to support integrating XML and GML with CAD and GIS systems
- Automation and enterprise services (FME Server)
Resources

FME Readers & Writers (CityGML Tutorial)
- docs.safe.com/fme/reader_writerPDF/citygml.pdf

CityGML specifications
- opengeospatial.org/standards/citygml

CityGML.org (Thomas Kolbe, etc)
- www.citygml.org/fileadmin/citygml/docs/CityGML_Tutorial_Kolbe_Internet.pdf

Safe.com
- safe.com/solutions/for-data-types/3d/

FMEPedia
- fmepedia.safe.com/topic/3D
Thank You!

For more information, contact:

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▪️Support@safe.com

Free Evaluation:
▪️www.safe.com/fme/fme-technology/fme-desktop/trial-download/