IFC-to-RDF: adaptation, aggregation and enrichment

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Ghent
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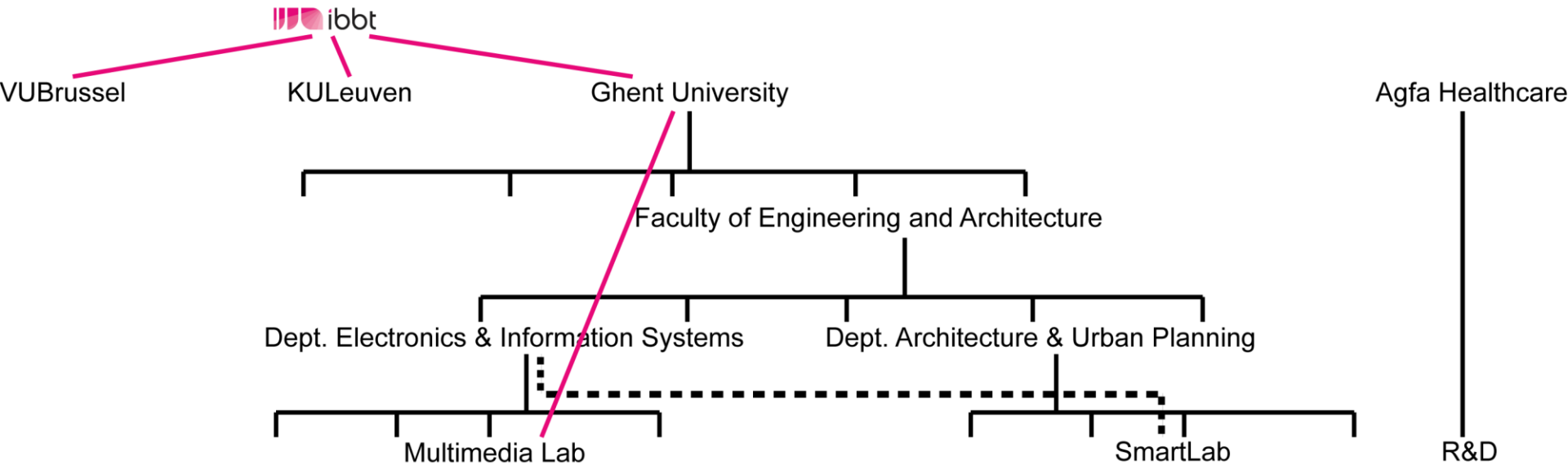
Outline

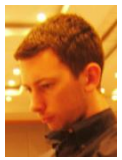
1. Research context: SMML collaboration
2. Towards interoperability with SMML
3. The IFC-to-RDF web service
4. Smart Virtual Environments
5. Semantic Building Performance Checking
6. Interoperability of 3D information

RESEARCH CONTEXT: SMML COLLABORATION

Multimedia Lab - SmartLab




Erik


Davy


Pieter

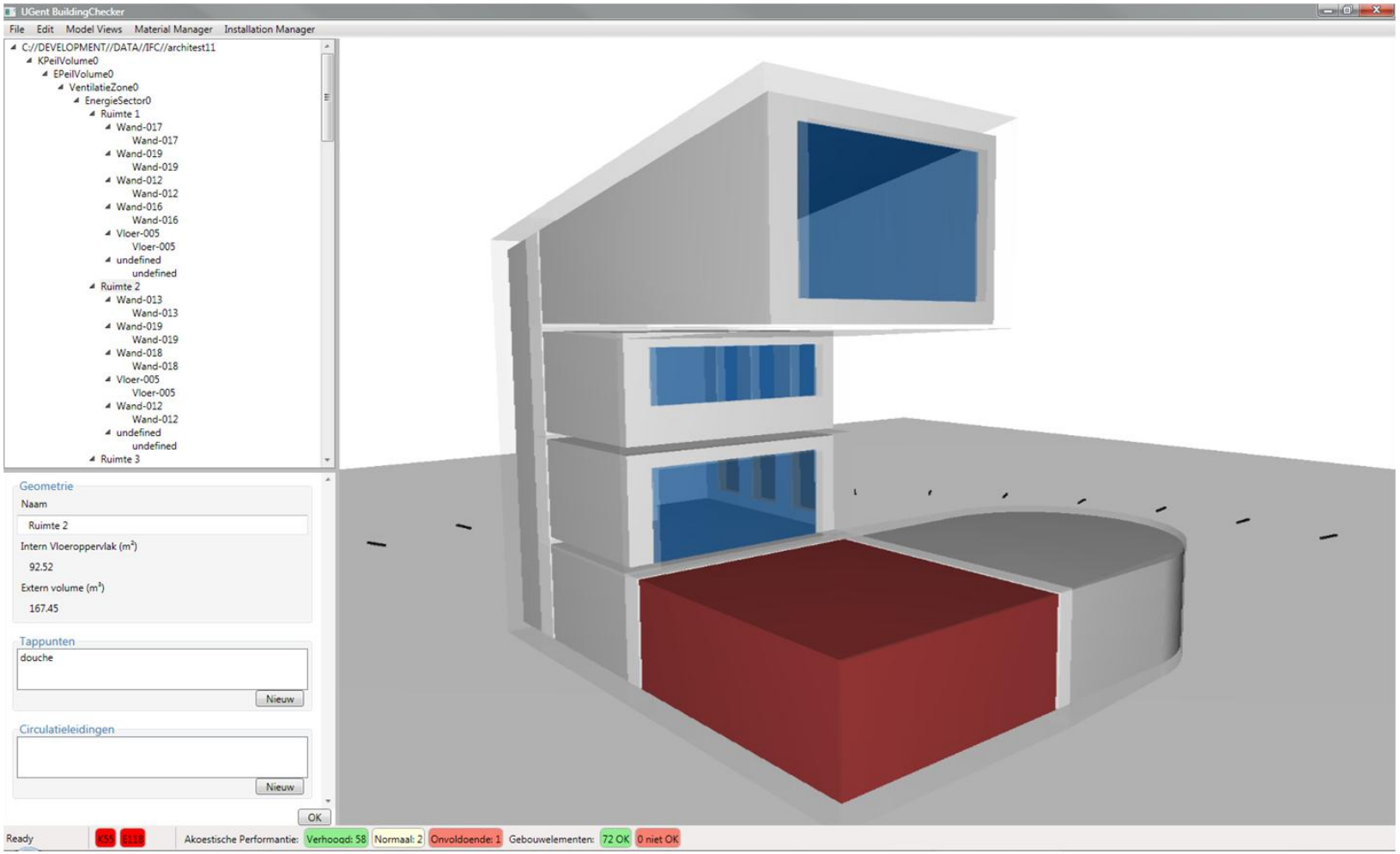

Ruben


Jos

SmartLab – Research topics

- Building Information Modelling and Interoperability in AEC:
  - Industry Foundation Classes (IFC)
  - Semantic web and rules (N3Logic)
- Visualisation applications in AEC:
  - gaming technology
  - VR/AR
  - rendering applications
- Calculation and simulation applications in AEC:
  - building performance checking
  - building code checking

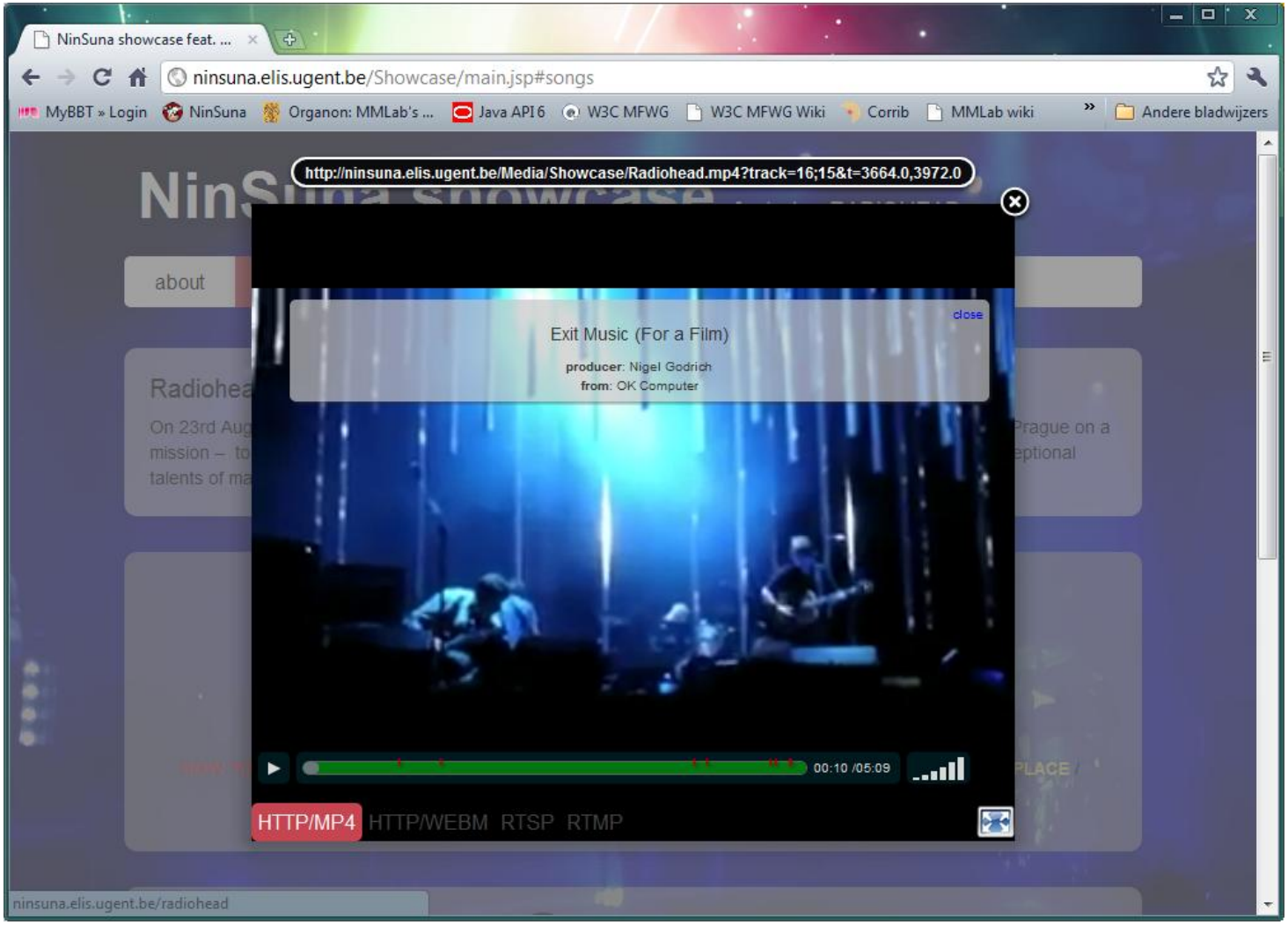
EPW Building Checker



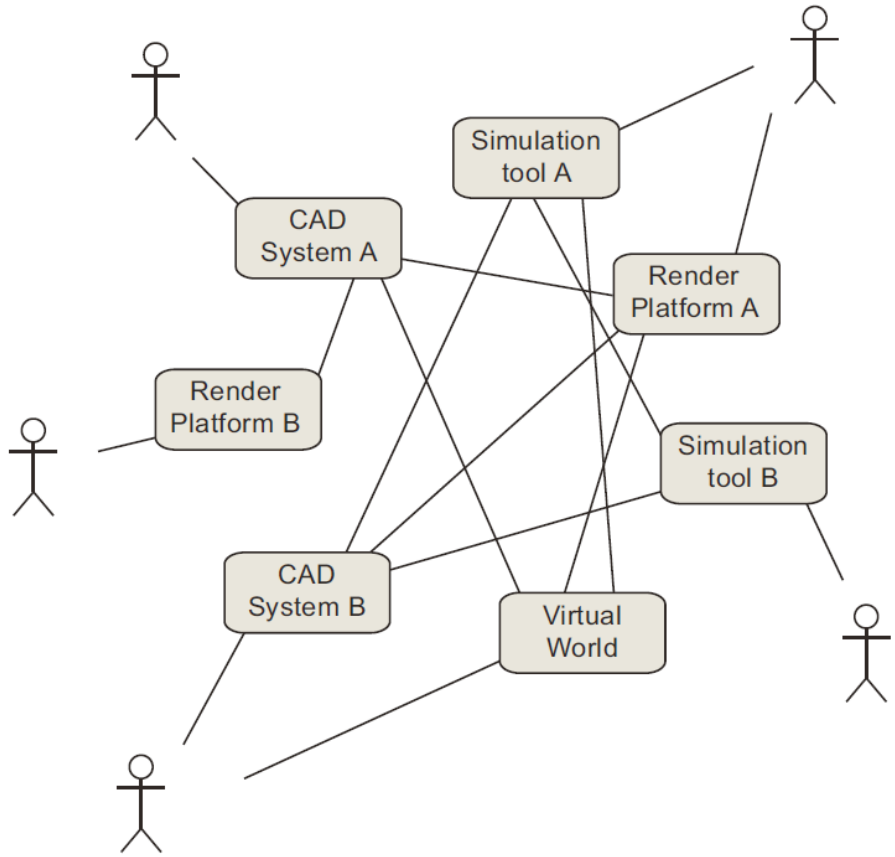
Multimedia Lab – research topics

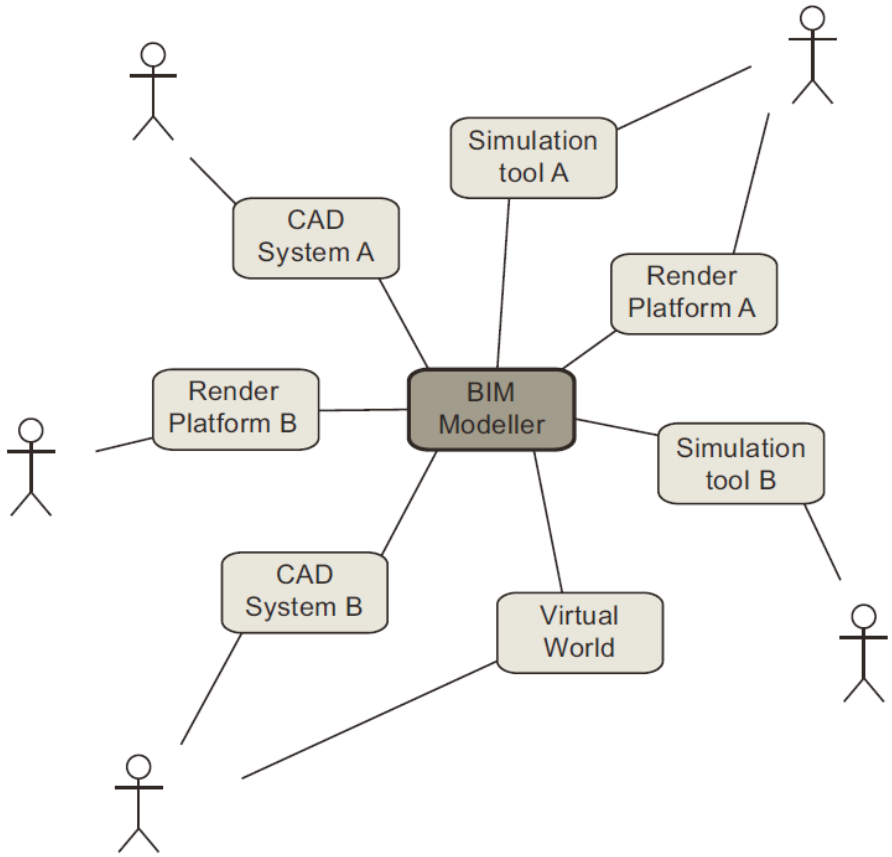
- Video coding and compression
- Image/video processing and analysis
- Multimedia content adaptation
- Metadata technology
- Gaming technology
- Standardization in the domain of multimedia applications and systems
  - W3C, VCEG/JVT, MPEG, VQEG

NinSuna: metadata-driven media adaptation & delivery



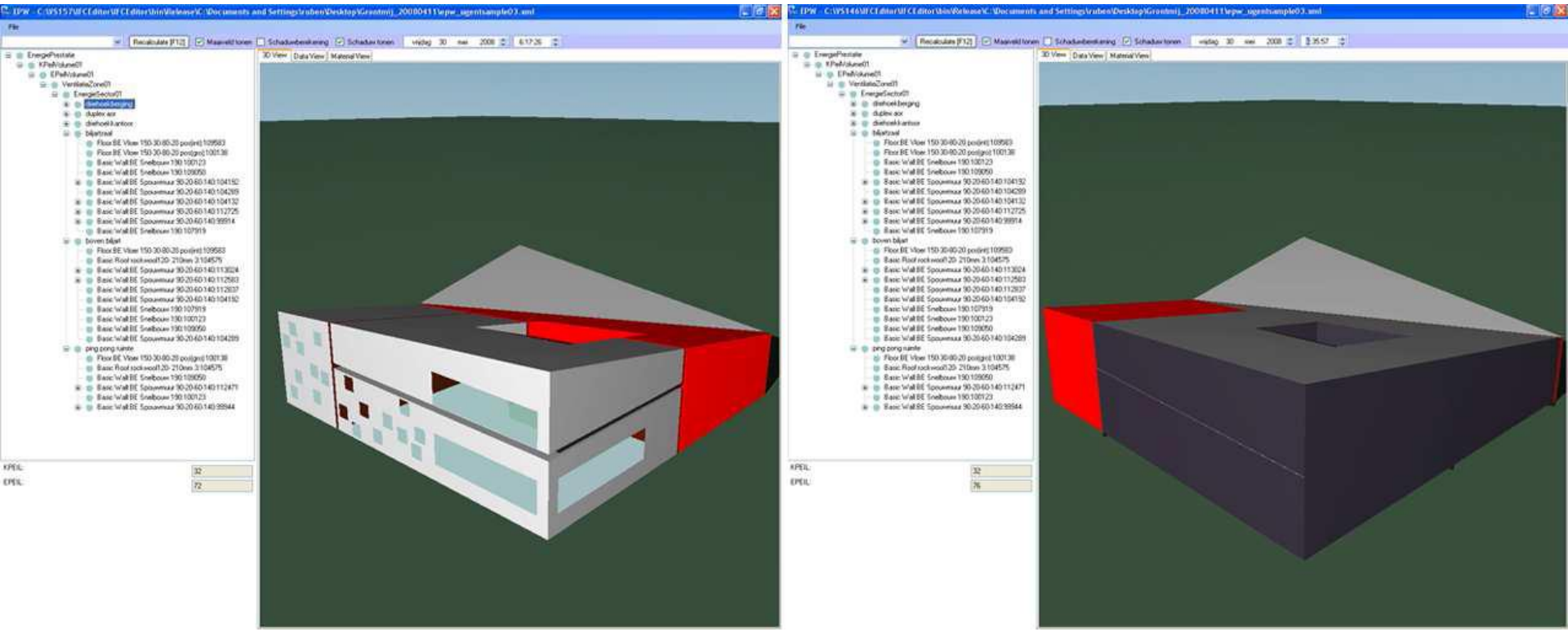
TOWARDS INTEROPERABILITY WITH SMML





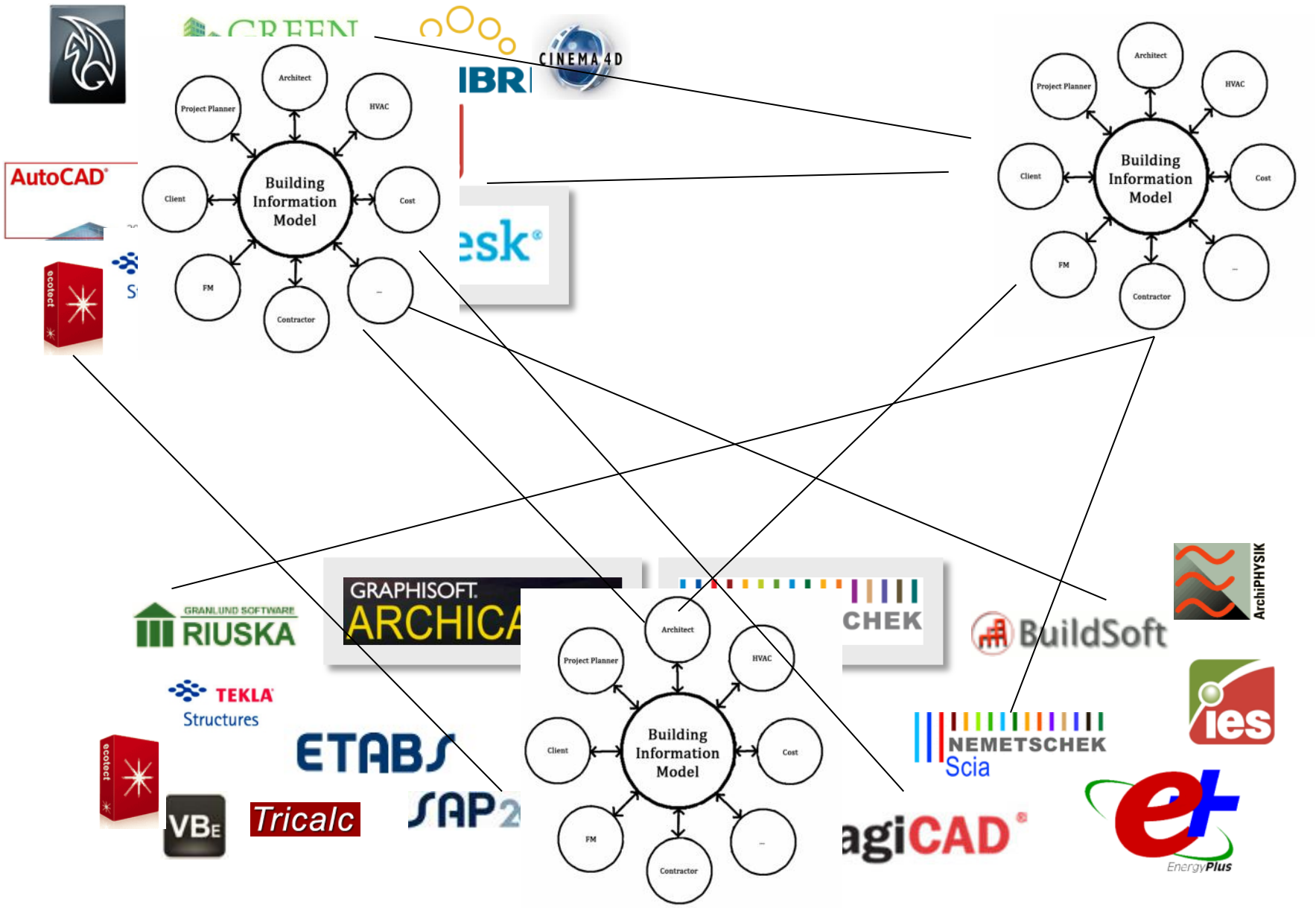
[1] P. Pauwels, R. De Meyer, J. Van Campenhout. Interoperability for the design and construction industry through semantic web technology. In: Proceedings of the 5th International Conference on Semantic and Digital Media Technologies (2010)

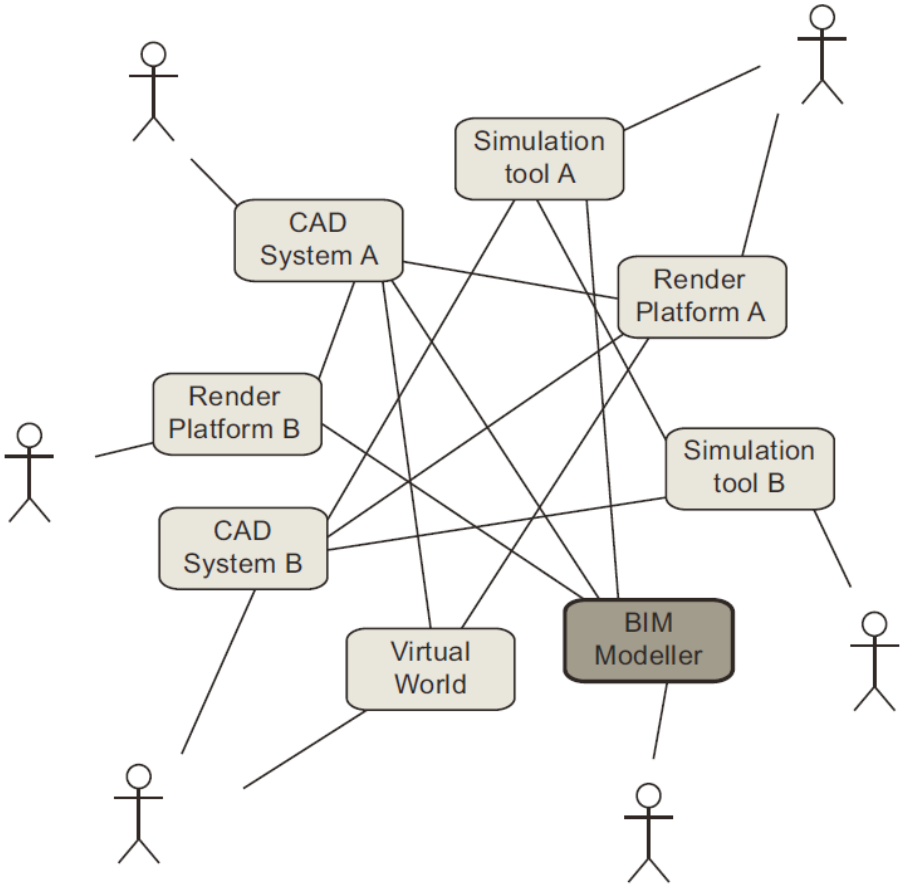
Energy Performance Simulation based on BIM/IFC

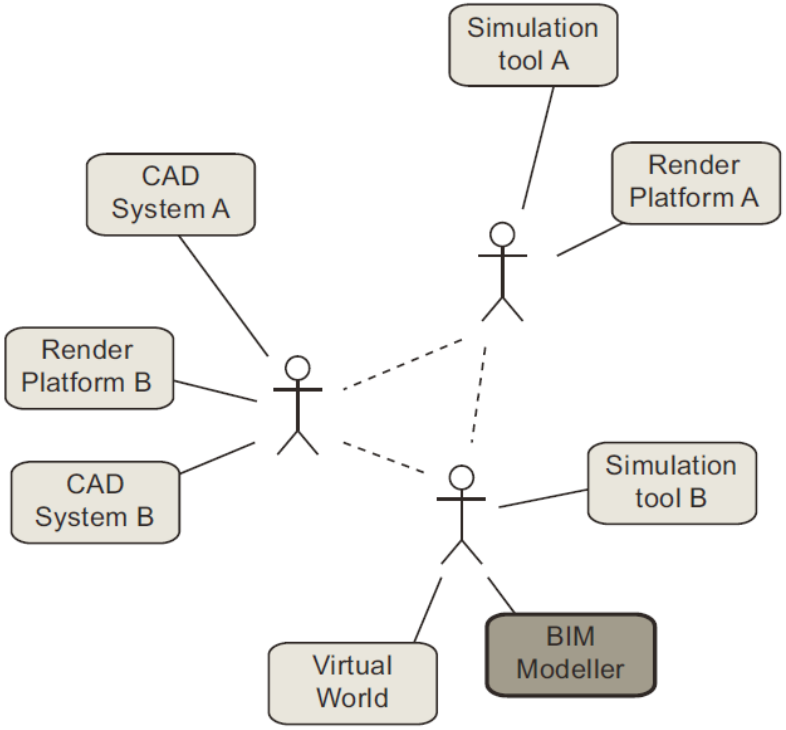


[2] R. Verstraeten, P. Pauwels, R. De Meyer, W. Meeus, J. Van Campenhout, G. Lateur. IFC-based calculation of the Flemish energy performance standard. In: Proceedings of the 7th European Conference on Product and Process Modelling 2008.

Current situation in construction industry







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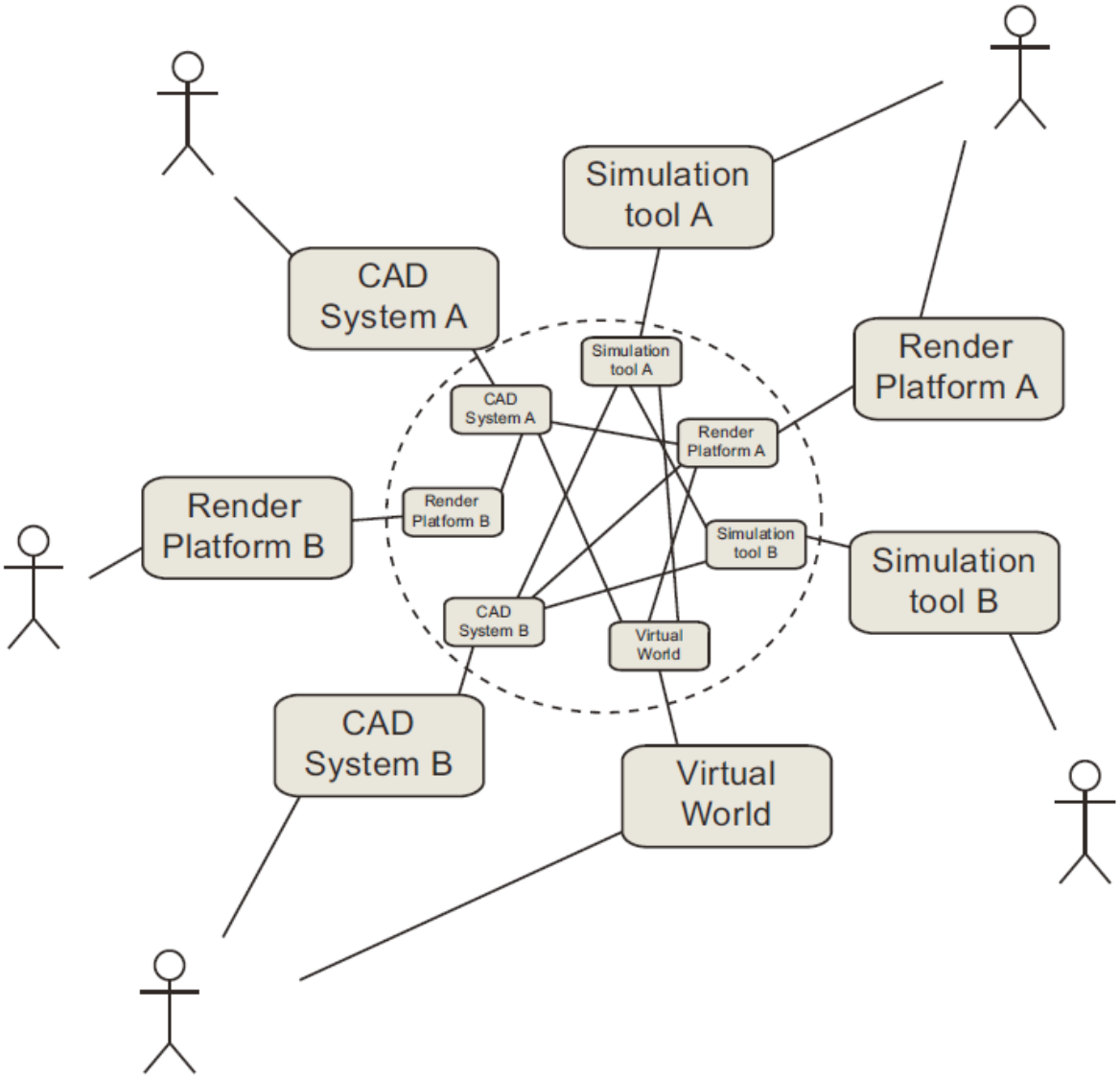
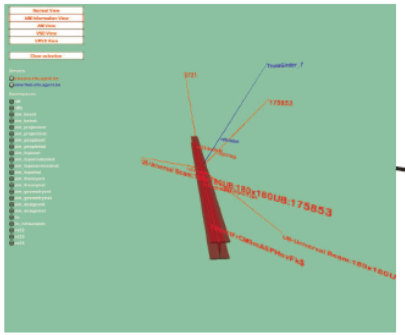
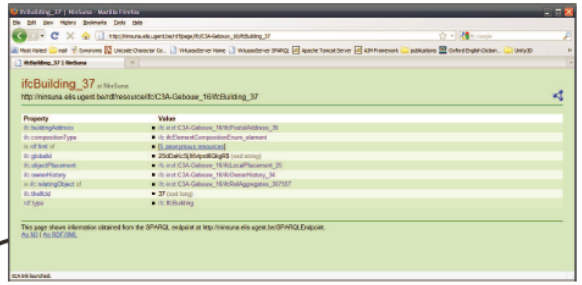


[1] P. Pauwels, R. De Meyer, J. Van Campenhout. Interoperability for the design and construction industry through semantic web technology. In: Proceedings of the 5th International Conference on Semantic and Digital Media Technologies (2010)

3D Game Environment

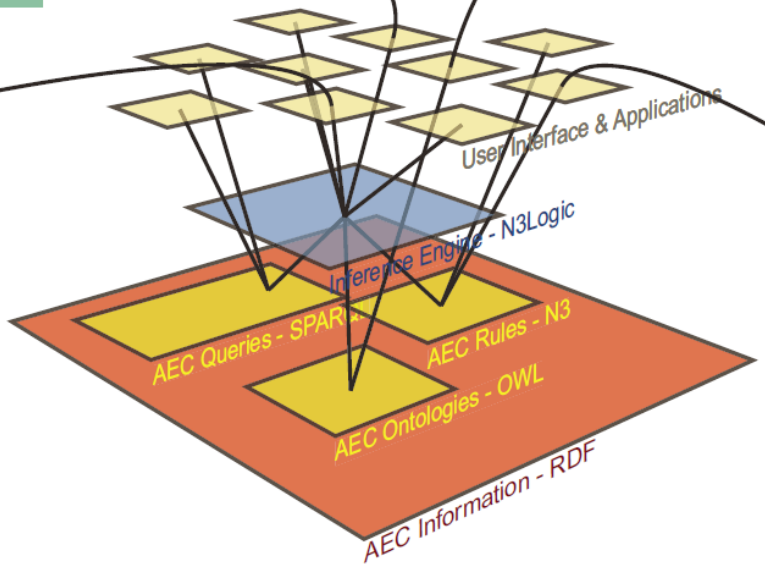


Semantic Web Interface

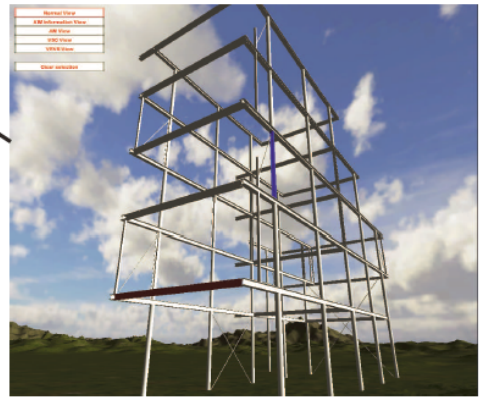


Semantic Building Checker

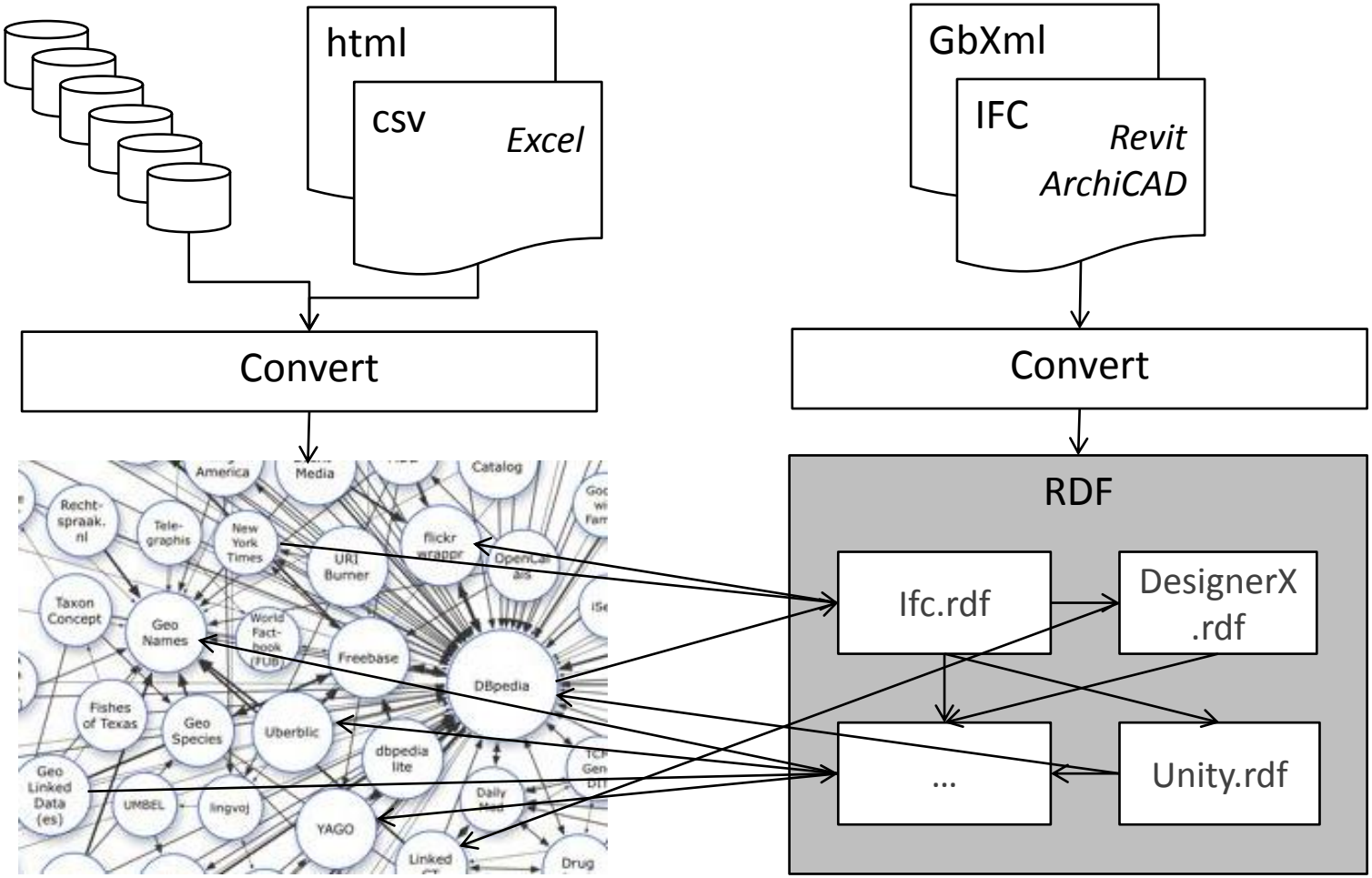
```
#Processed by
#$Id: euler.yap 3098 2009-08-24 20:31:17Z josd $

@prefix : [...]

inst:RoomBoundary_1
      NBNS014001:ComfortLevel    "normaal"^^xsd:string .
inst:RoomBoundary_2
      NBNS014001:ComfortLevel    "verhoogd"^^xsd:string .
inst:RoomBoundary_3
      NBNS014001:ComfortLevel    "normaal"^^xsd:string .
inst:RoomBoundary_4
      NBNS014001:ComfortLevel    "normaal"^^xsd:string .


#ENDS 16 msec
#Trunk : 94/326 = 28.8343558282209 %
#Branch: 1/93 = 1.0752688172043 %
```



3D Game Environment



THE IFC-TO-RDF WEB SERVICE


html
csv
Excel
GbXml
IFC
Revit
ArchiCAD
Convert
Convert
RDF
Ifc.rdf
DesignerX
.rdf
...
Unity.rdf
Recht-
spraak.
nl
Tele-
graphis
New
York
Times
URI
Burner
flickr
wrappr
Taxon
Concept
Geo
Names
World
Fact-
book
(FUB)
Freebase
DBpedia
Fishes
of Texas
Geo
Species
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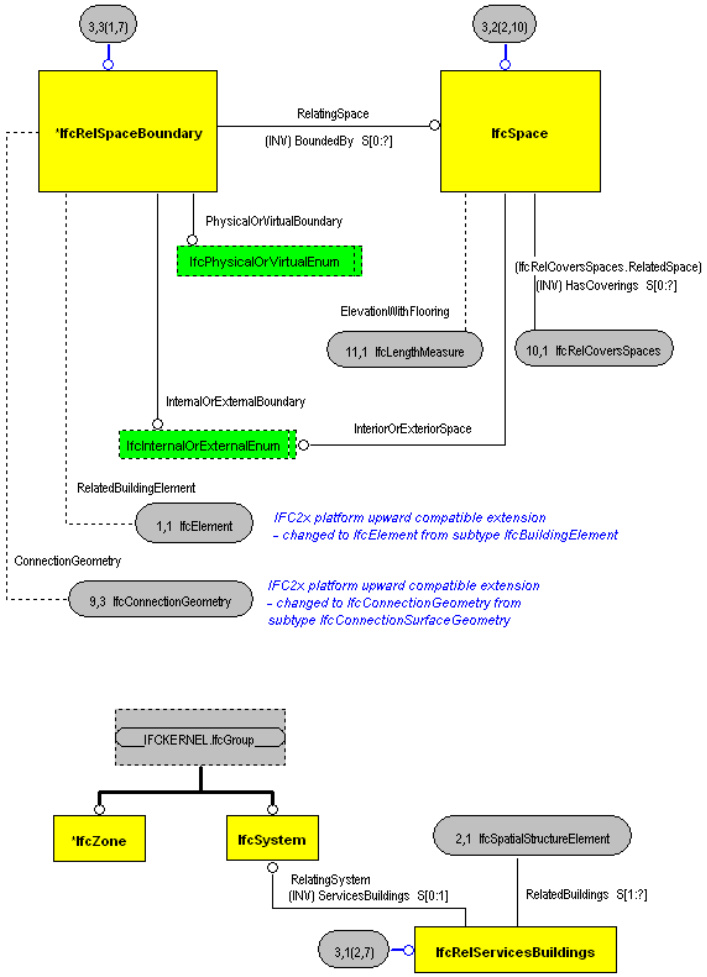
lingvoj
YAGO
Drug

IFC-to-RDF



Mapping schema's:

1. ifcXML to RDF/XML via XSLT transformation
    1. Light-weight: conversion can occur completely on an instance level
    2. Time-consuming and prone to errors: it takes time and concentration to build the XSLT file
    3. Limited expressiveness of RDF/XML format (no rule functionality)
2. Translate EXPRESS schema to OWL ontology and use the ontology to build RDF instance graphs
    1. Less prone to errors: once the mapping between EXPRESS elements and OWL elements is made, everything goes smoothly and correctly
    2. High expressiveness because of N3 syntax

[3] P. Pauwels, D. Van Deursen, R. Verstraeten, J. De Roo, R. De Meyer, R. Van de Walle, J. Van Campenhout. A semantic rule checking environment for building performance checking. Automation in Construction 20(5) 2011, 506-518.

RDF view on IFC

- IFC specification is written in EXPRESS

```
ENTITY IfcDoor
  SUBTYPE OF ( IfcBuildingElement);
  OverallHeight  :  OPTIONAL IfcPositiveLengthMeasure;
  OverallWidth  :  OPTIONAL IfcPositiveLengthMeasure;
END_ENTITY;
```

- Two tasks
  - automatic transformation of EXPRESS to OWL
  - automatic conversion of IFC to RDF instances

EXPRESS => OWL

- Not really new
  - related work on EXPRESS-to-OWL conversion
  - related work on IFC-to-OWL conversion
    - J. Beetz, J. van Leeuwen, B. de Vries, IfcOWL: a case of transforming EXPRESS schemas into ontologies, Artificial Intelligence for Engineering Design Analysis and Manufacturing (AI EDAM) 23 (1) (2009) 89–101
- We did it to get started

EXPRESS => OWL

- Entity -> owl:Class

```
ENTITY IfcRelationship
 ABSTRACT SUPERTYPE OF (ONEOF (IfcRelDefines, IfcRelAssociates))
 SUBTYPE OF (IfcRoot);
END_ENTITY;

ENTITY IfcRelDefines
 SUBTYPE OF (IfcRelationship);
END_ENTITY;
```

```
ifc:IfcRelationship
        rdfs:subClassOf ifc:IfcRoot;
        a owl:Class.

ifc:IfcRelDefines
        rdfs:subClassOf ifc:IfcRelationship;
        owl:disjointWith ifc:IfcRelAssociates;
        a owl:Class.
```

EXPRESS => OWL

- Attribute -> owl:DatatypeProperty

```
TYPE IfcPlaneAngleMeasure = REAL;
END_TYPE;

ENTITY IfcLightDistributionData;
        MainPlaneAngle : IfcPlaneAngleMeasure;
END_ENTITY;
```

```
ifc:mainPlaneAngle
        rdfs:domain ifc:IfcLightDistributionData;
        rdfs:range xsd:double;
        a owl:DatatypeProperty.
```

EXPRESS => OWL

- Attr dvanced)

```
TYPE IfcRatioMeasure = REAL;
END_TYPE;

TYPE IfcPositiveRatioMeasure = IfcRatioMeasure;
 WHERE
        WR1 : SELF > 0.0;
END_TYPE;

ENTITY IfcProductsOfCombustionProperties
        CO2Content : IfcPositiveRatioMeasure;
END_ENTITY;
```

```
ifc:cO2Content
        rdfs:domain ifc:IfcProductsOfCombustionProperties;
        rdfs:range xsd:double;
        a owl:DatatypeProperty.

{?x a ifc:IfcProductsOfCombustionProperties. ?x ifc:cO2Content
?y. ?y math:notGreaterThan 0.0.} => false.
```

EXPRESS => OWL

- SELECT for entities/types => owl:unionOf-based class in rdfs:range
- ENUM types => rdfs:subClass with owl:one of
- List types => rdf:List

EXPRESS => OWL

- Ontology available at http://multimedialab.elis.ugent.be/organon/ontologies/IFC2X3

- Issues
  - property name conflicts
    - RDF => classes and properties independent
    - EXPRESS => properties are declared with classes
  - automatic generation of N3 rules
- TODOs
  - OPTIONAL keyword should be mapped to OWL cardinality restrictions
  - UNIQUE and DERIVE keywords are not considered for the moment

IFC instances => RDF

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION (('IFC Engine Kernel version 1.11 beta.'), '2;1');
FILE_SCHEMA (('IFC2X3'));
ENDSEC;
DATA;
#1 = IFCORGANIZATION($, 'Revit Architecture 2009', $, $, $);
#2 = IFCAPPLICATION(#1, '2009', 'Revit Architecture 2009', 'Revit');
#3 = IFCCARTESIANPOINT((0.,0.,0.));
...
#4796 = IFCAXIS2PLACEMENT3D(#3,$,$);
#4797 = IFCLOCALPLACEMENT(#4714,#4796);
#4798 = IFCDOOR('Z921',#33,$,#4797,#4792,'110146',2134.,914.9);
...
```

IFC instances => RDF

- Pretty straightforward from a conceptual point of view
  - Instance naming
    - name of the type + line number
      - #4796 = IFCAXIS2PLACEMENT3D(#3,$,$);
        => ifcAxis2Placement3D_4796
- Not so straightforward from a practical point of view
  - memory issues (triples are directly saved in RDF store)
  - slow conversion progress (no optimized implementation)

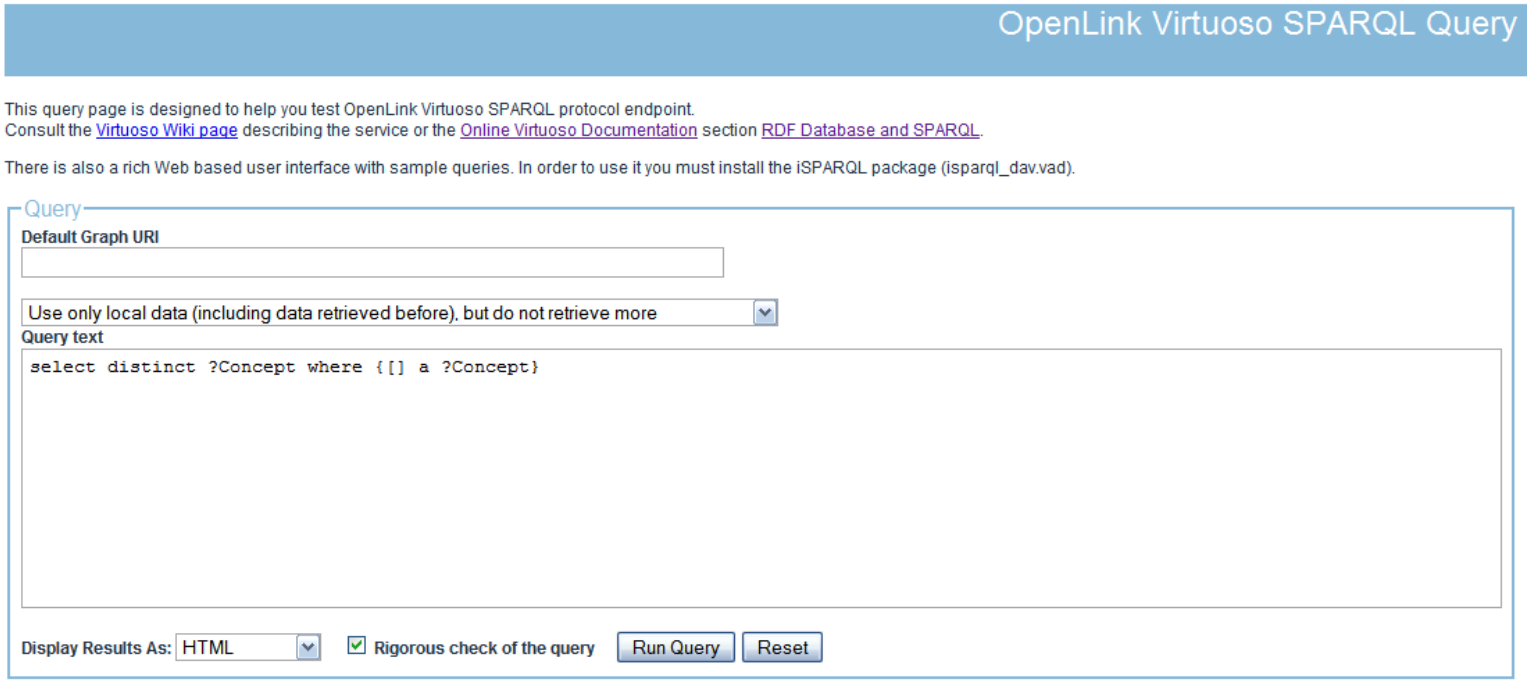
```
@prefix : <http://multimedialab.elis.ugent.be/ontologies/ifc/instances#>.
@prefix ifc: <http://multimedialab.elis.ugent.be/ontologies/ifc/ontology#>.
@prefix list: <http://www.co-ode.org/ontologies/lists/2008/09/11/list.owl#>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.

:ifcOrganization_1
        ifc:name "Autodesk Revit Architecture 2010"^^xsd:normalizedString;
        ifc:theIfcId "1"^^xsd:long;
        rdf:type ifc:IfcOrganization.

:ifcApplication_2
        ifc:applicationDeveloper :ifcOrganization_1;
        ifc:version "2010"^^xsd:normalizedString;
        ifc:applicationFullName "Autodesk Revit Architecture 2010"^^xsd:normalizedString;
        ifc:applicationIdentifier "Revit"^^xsd:normalizedString;
        ifc:theIfcId "2"^^xsd:long;
        rdf:type ifc:IfcApplication.

:ifcCartesianPoint_4
        ifc:coordinates  ( "0.0"^^xsd:double "0.0"^^xsd:double );
        ifc:theIfcId "4"^^xsd:long;
        rdf:type ifc:IfcCartesianPoint.

:ifcDirection_5
        ifc:directionRatios  ( "1.0"^^xsd:double "0.0"^^xsd:double "0.0"^^xsd:double );
        ifc:theIfcId "5"^^xsd:long;
        rdf:type ifc:IfcDirection.

:ifcDirection_10
        ifc:directionRatios  ( "0.0"^^xsd:double "0.0"^^xsd:double "-1.0"^^xsd:double );
        ifc:theIfcId "10"^^xsd:long;
        rdf:type ifc:IfcDirection.

:ifcDirection_11
        ifc:directionRatios  ( "1.0"^^xsd:double "0.0"^^xsd:double );
        ifc:theIfcId "11"^^xsd:long;
```

Upload IFC information into IFC/RDF graph

http://ninsuna.elis.ugent.be/IfcRDFService

Query IFC/RDF graph

http://ninsuna.elis.ugent.be/SPARQLEndpoint



Browse IFC/RDF graph

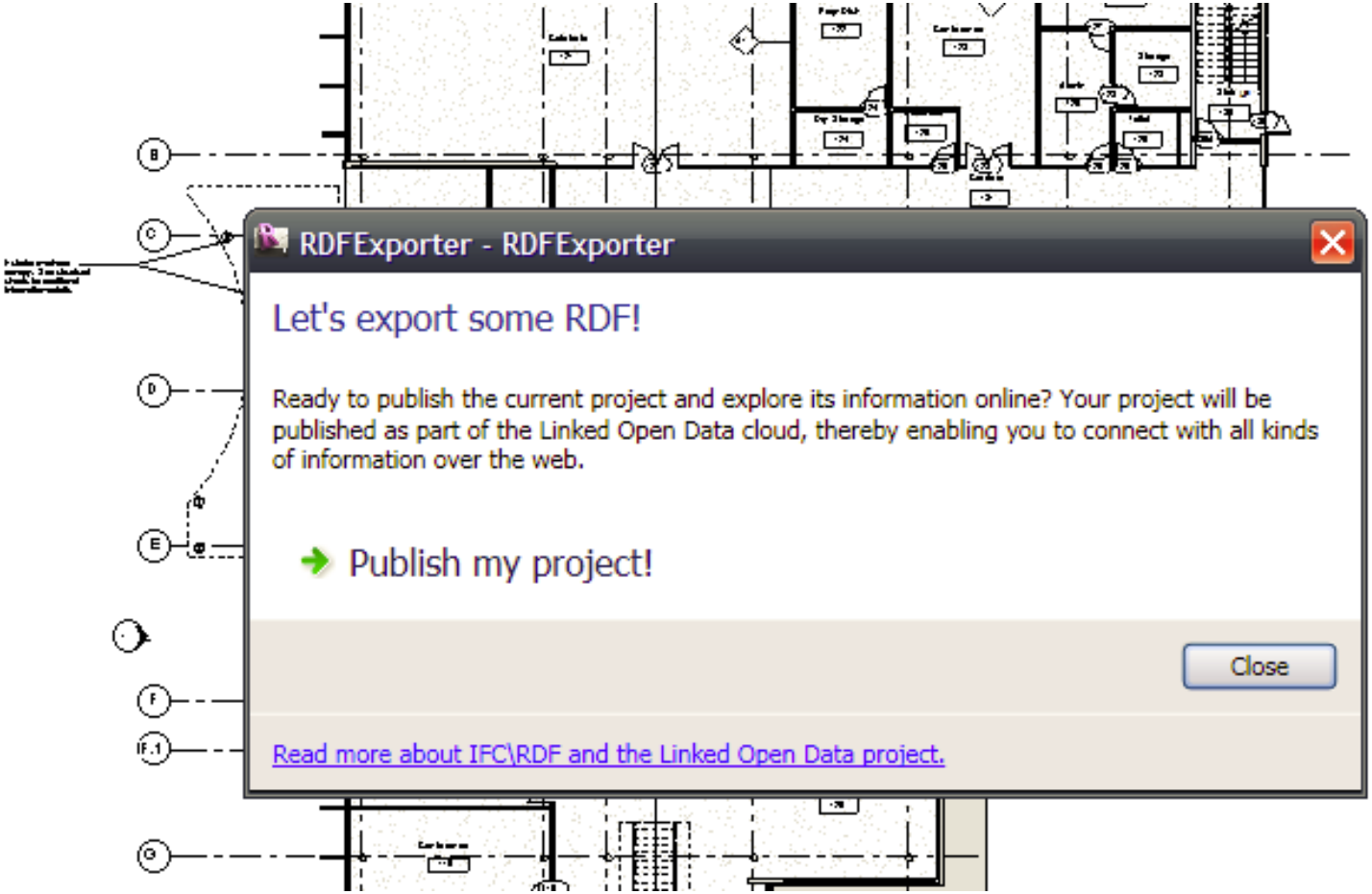
http://ninsuna.elis.ugent.be/rdf/page/ifc/IFC2X3_TC1/ifcBuilding_36

ifcBuilding_36 at NinSuna

http://ninsuna.elis.ugent.be/rdf/resource/ifc/IFC2X3_TC1/ifcBuilding_36

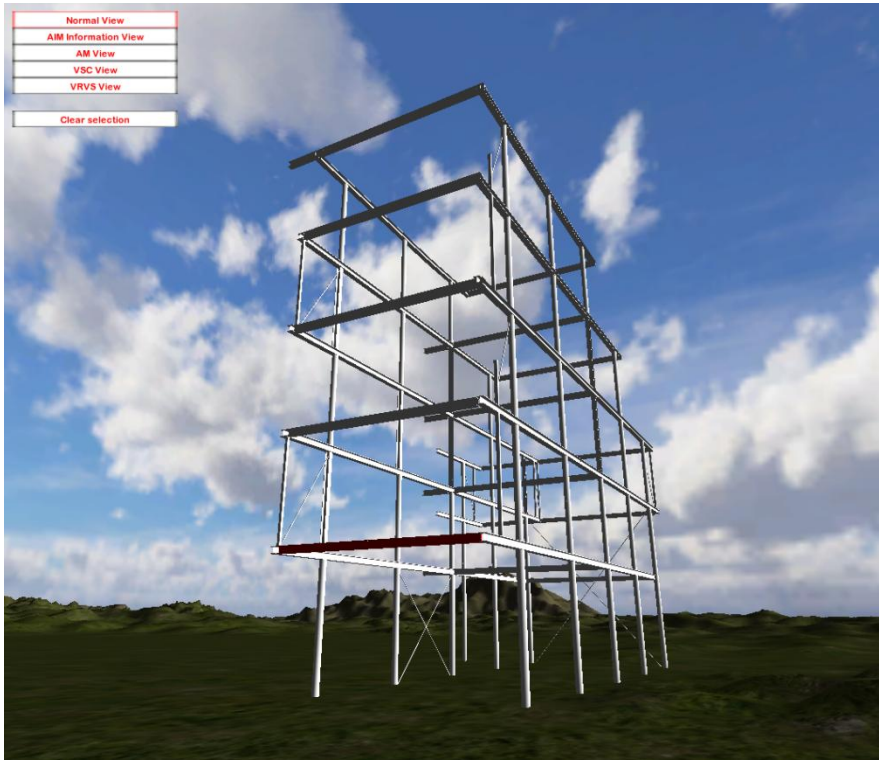
Property	Value
ifc:buildingAddress	ifc-inst:IFC2X3_TC1/ifcPostalAddress_35
ifc:compositionType	ifc:ifcElementCompositionEnum_element
is rdf:first of	[1 anonymous resource]
ifc:globalId	2uXRFQpW95KAoBFXcolOBT (xsd:string)
ifc:objectPlacement	ifc-inst:IFC2X3_TC1/ifcLocalPlacement_25
ifc:ownerHistory	ifc-inst:IFC2X3_TC1/ifcOwnerHistory_33
is ifc:relatingObject of	ifc-inst:IFC2X3_TC1/ifcRelAggregates_268
ifc:theIfcId	36 (xsd:long)
rdf:type	ifc:IfcBuilding

This page shows information obtained from the SPARQL endpoint at http://ninsuna.elis.ugent.be/SPARQLEndpoint.
As N3 | As RDF/XML


RDFExporter - RDFExporter
Let's export some RDF!
Ready to publish the current project and explore its information online? Your project will be published as part of the Linked Open Data cloud, thereby enabling you to connect with all kinds of information over the web.
Publish my project!
Close
Read more about IFC\RDF and the Linked Open Data project.

SMART VIRTUAL ENVIRONMENTS

visualisation in Unity game engine



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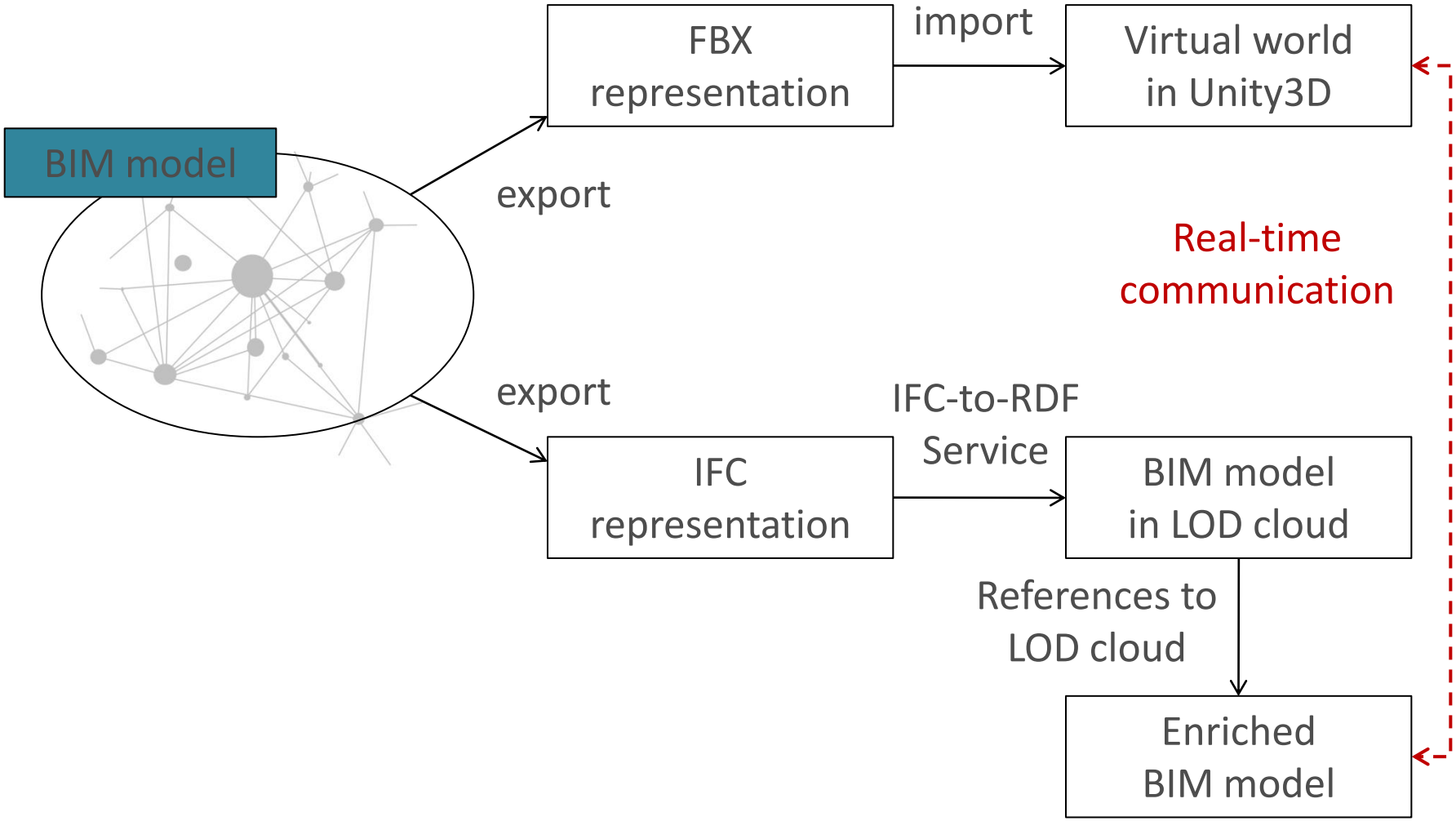
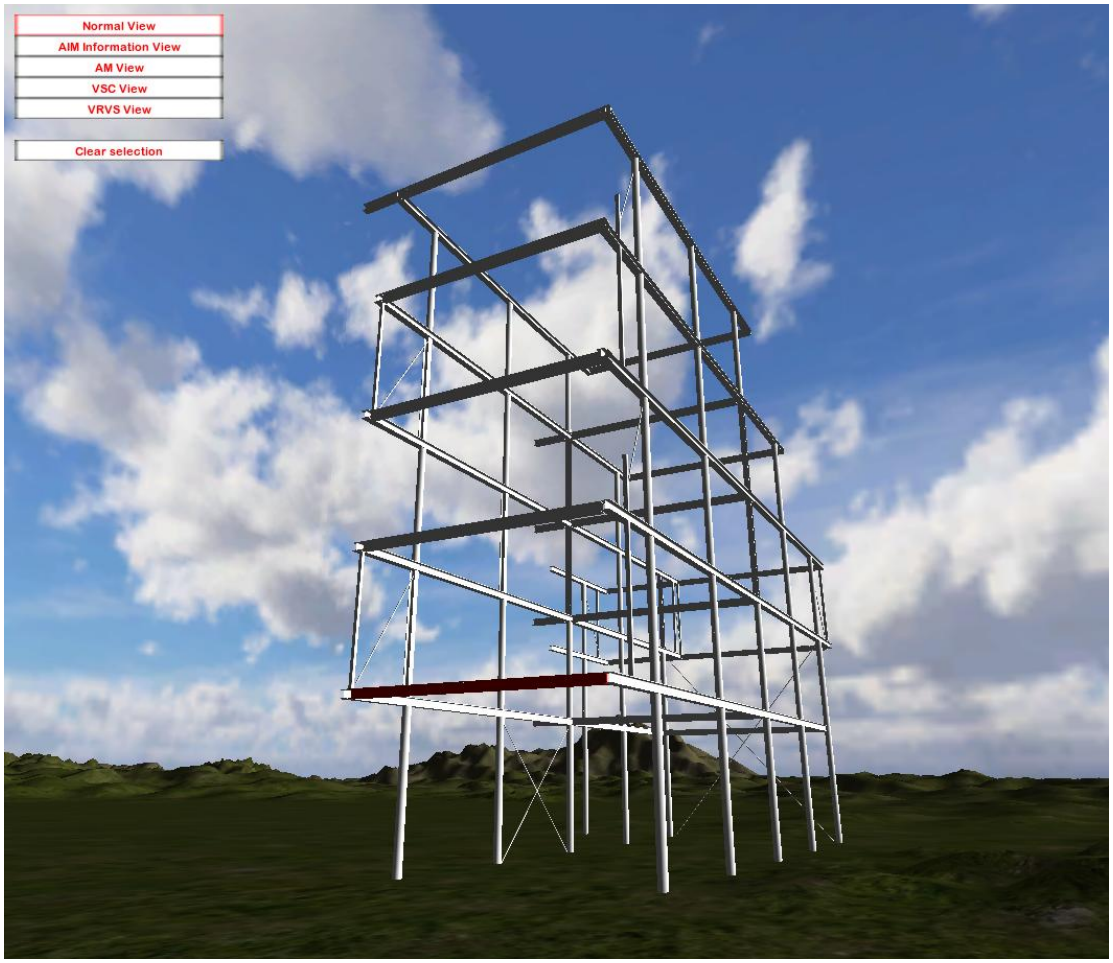
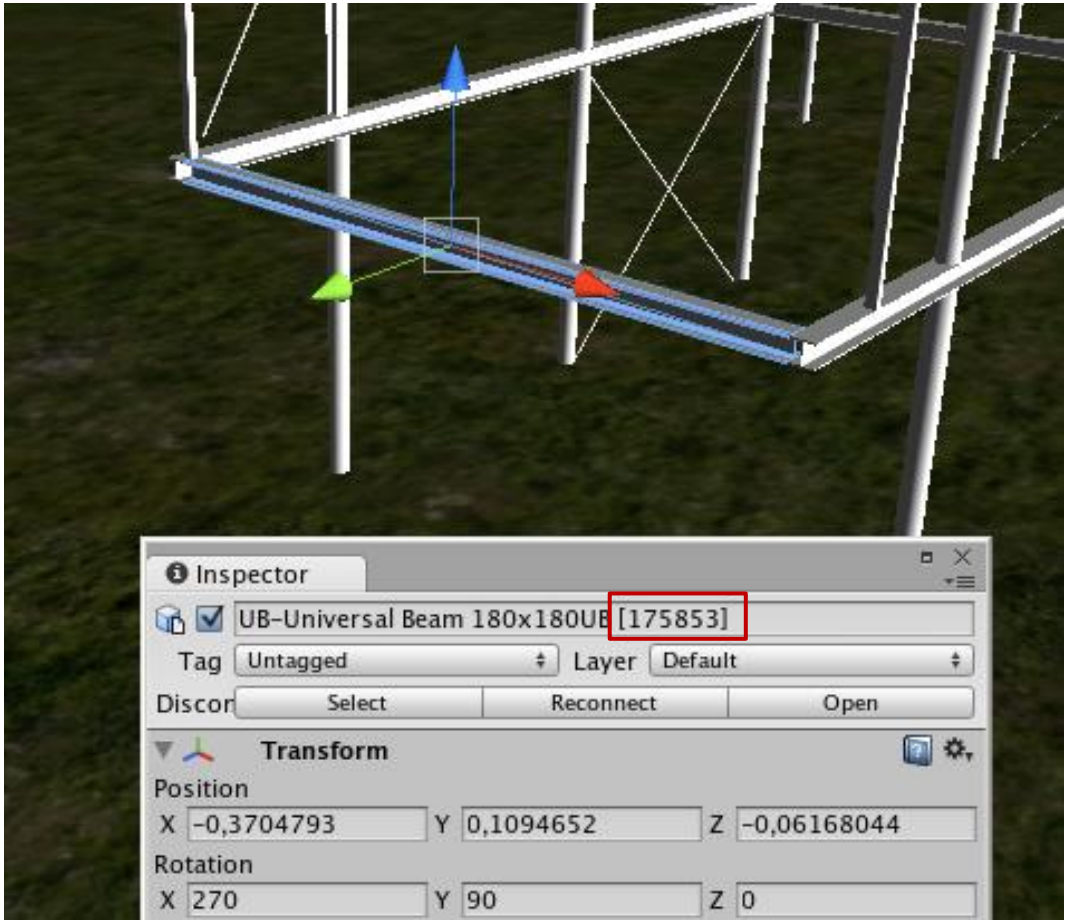

BIM model
export
FBX representation
import
Virtual world in Unity3D
Real-time communication
export
IFC representation
IFC-to-RDF Service
BIM model in LOD cloud
References to LOD cloud
Enriched BIM model

Creation of the virtual world



[3] P. Pauwels, R. De Meyer, J. Van Campenhout. Visualisation of semantic architectural information within a game engine environment. In: Proceedings of the 10th International Conference on Construction Applications of Virtual Reality 2010.

Connecting FBX representation to the IFC/RDF graph (1)



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Connecting FBX representation to the IFC/RDF graph (2)

```
SELECT distinct ?s WHERE {
    ?s <http://multimedialab.organon.elis.ugent.be/ontologies/IFC2X3#tag>
    "175853"^^xsd:string .
    ?s <http://multimedialab.organon.elis.ugent.be/ontologies/IFC2X3#representation> ?o
}
```

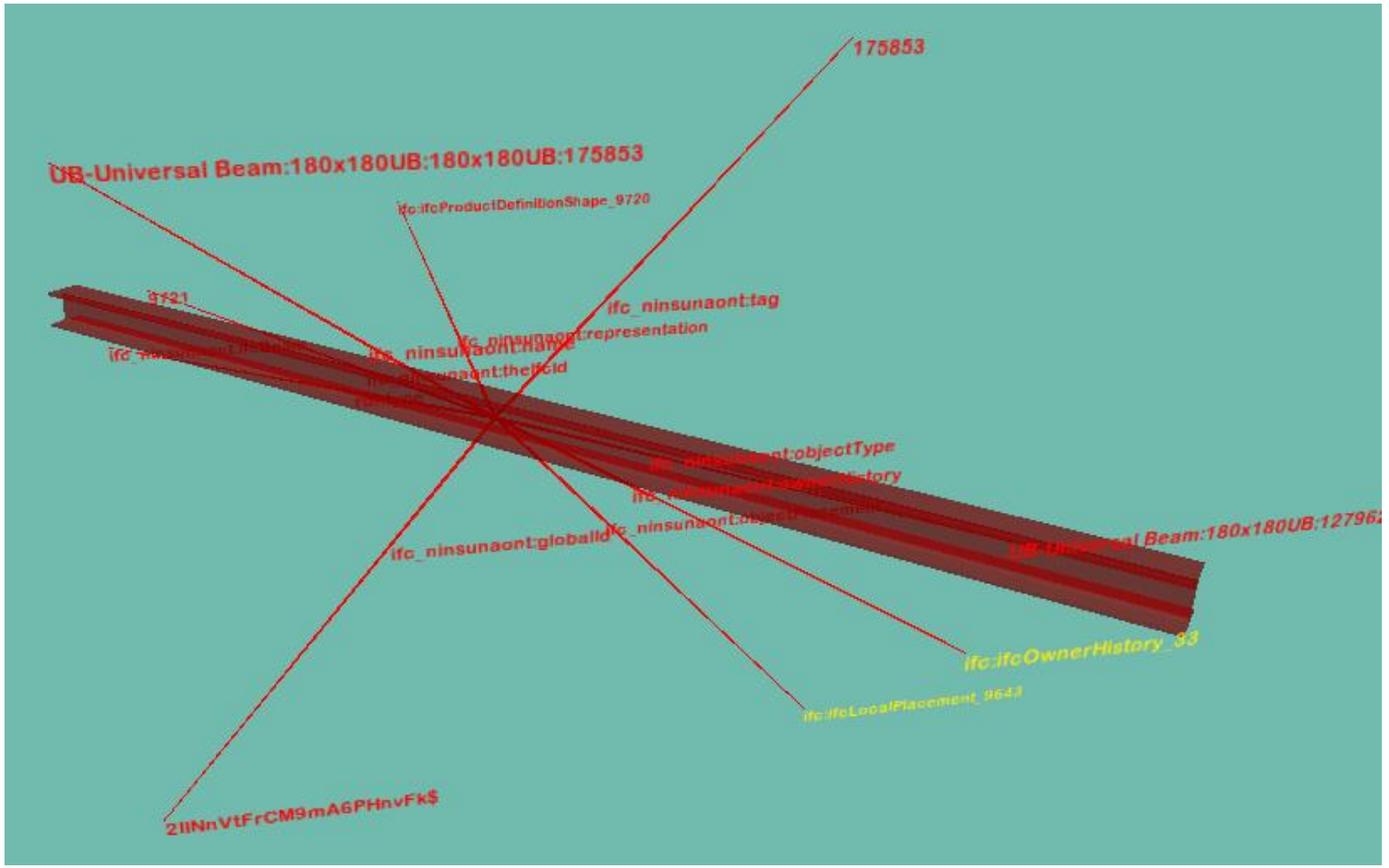
ifcBeam_9721 at NinSuna

http://ninsuna.elis.ugent.be/rdf/resource/ifc/20100113_statiestraatstructuur/ifcBeam_9721

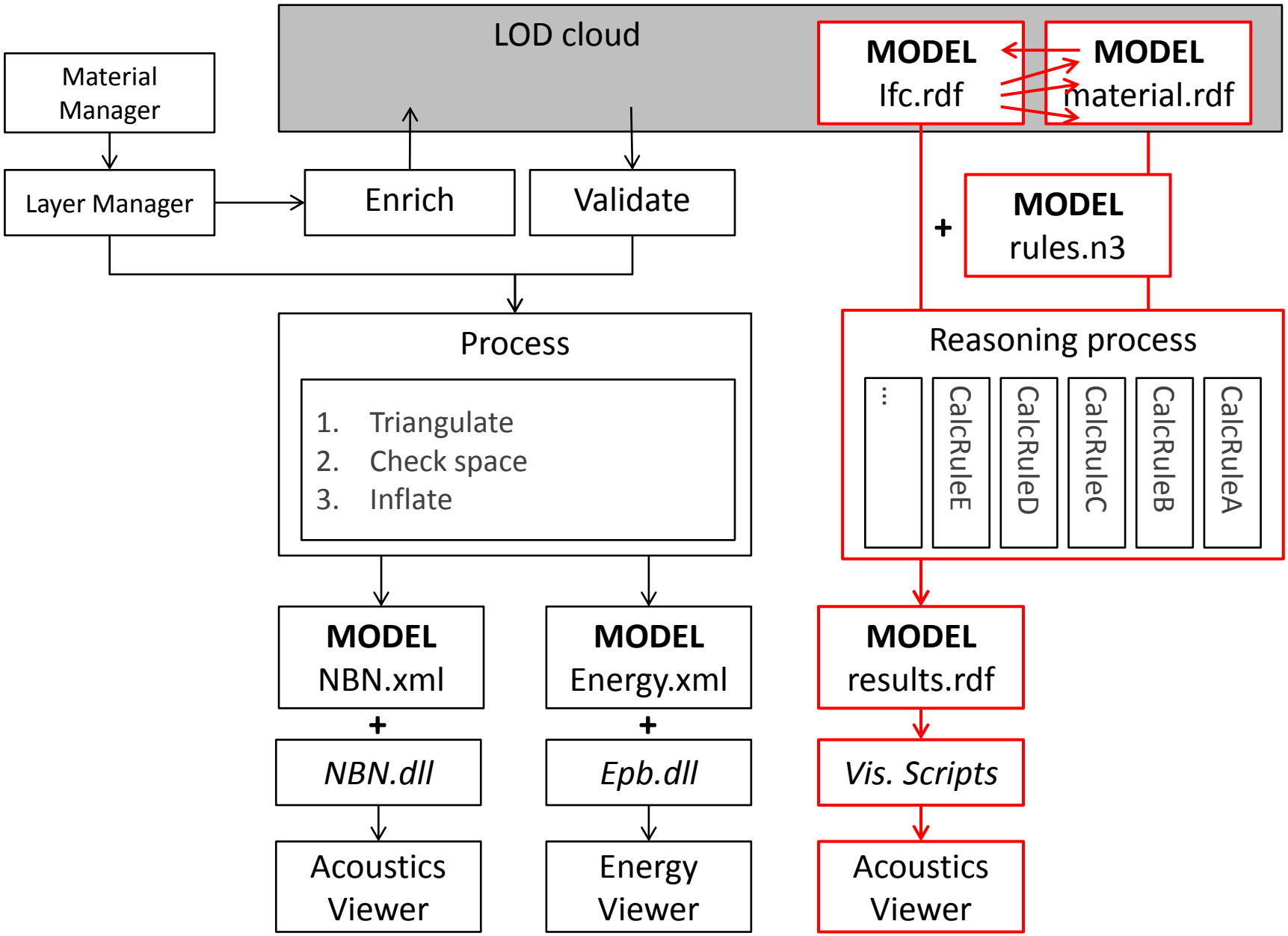
Property	Value
is rdf:first of	[30 anonymous resources]
ifc:globalId	2llNnVtFrCM9mA6PHnvFk$ (xsd:string)
ifc:name	UB-Universal Beam:180x180UB:180x180UB:175853 (xsd:string)
ifc:objectPlacement	ifc-inst:20100113_statiestraatstructuur/ifcLocalPlacement_9643
ifc:objectType	UB-Universal Beam:180x180UB:127962 (xsd:string)
ifc:ownerHistory	ifc-inst:20100113_statiestraatstructuur/ifcOwnerHistory_33
ifc:representation	ifc-inst:20100113_statiestraatstructuur/ifcProductDefinitionShape_9720
ifc:tag	175853 (xsd:string)
ifc:thelfcId	9721 (xsd:long)
rdf:type	ifc:IfcBeam

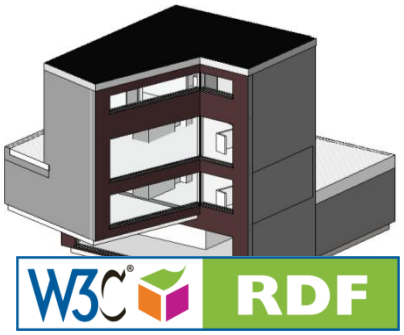
This page shows information obtained from the SPARQL endpoint at http://ninsuna.elis.ugent.be/SPARQLEndpoint.
As N3 | As RDF/XML

Basic user interface



SEMANTIC BUILDING PERFORMANCE CHECKING


LOD cloud
MODEL
Ifc.rdf
MODEL
material.rdf
Material Manager
Layer Manager
Enrich
Validate
+
MODEL
rules.n3
Process
1. Triangulate
2. Check space
3. Inflate
Reasoning process
…
CalcRuleE
CalcRuleD
CalcRuleC
CalcRuleB
CalcRuleA
MODEL
NBN.xml
+
NBN.dll
Acoustics Viewer
MODEL
Energy.xml
+
Epb.dll
Energy Viewer
MODEL
results.rdf
Vis. Scripts
Acoustics Viewer



W3C RDF

instance of

IFC

W3C OWL

Reasoner

materials databases

W3C SPARQL

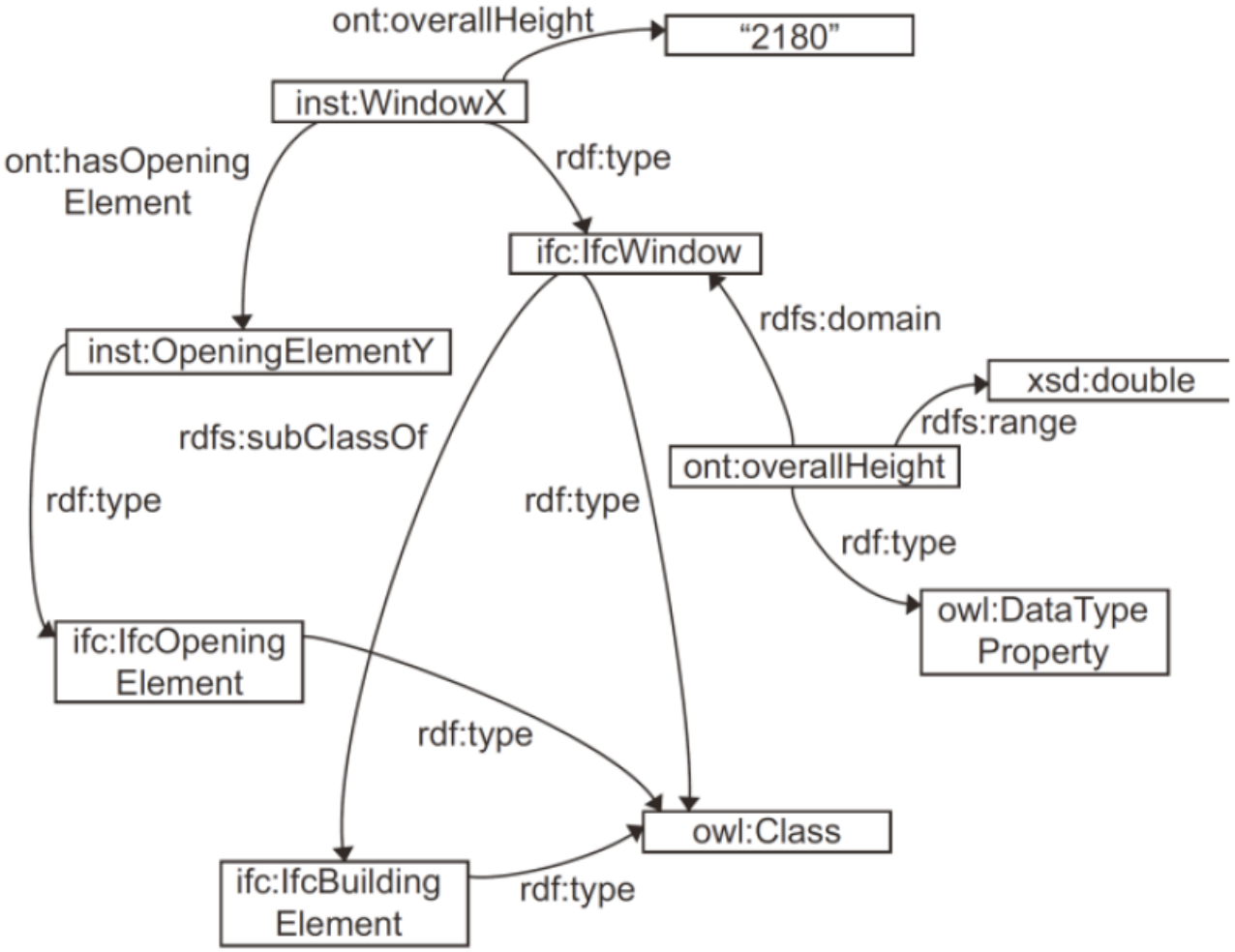
NBN S01-400-1

N3 rules

standards and application-specific calculations

[4] P. Pauwels, D. Van Deursen, R. Verstraeten, J. De Roo, R. De Meyer, R. Van de Walle, J. Van Campenhout. A semantic rule checking environment for building performance checking. Automation in Construction 20(5) 2011, 506-518.

Description of ‘facts’



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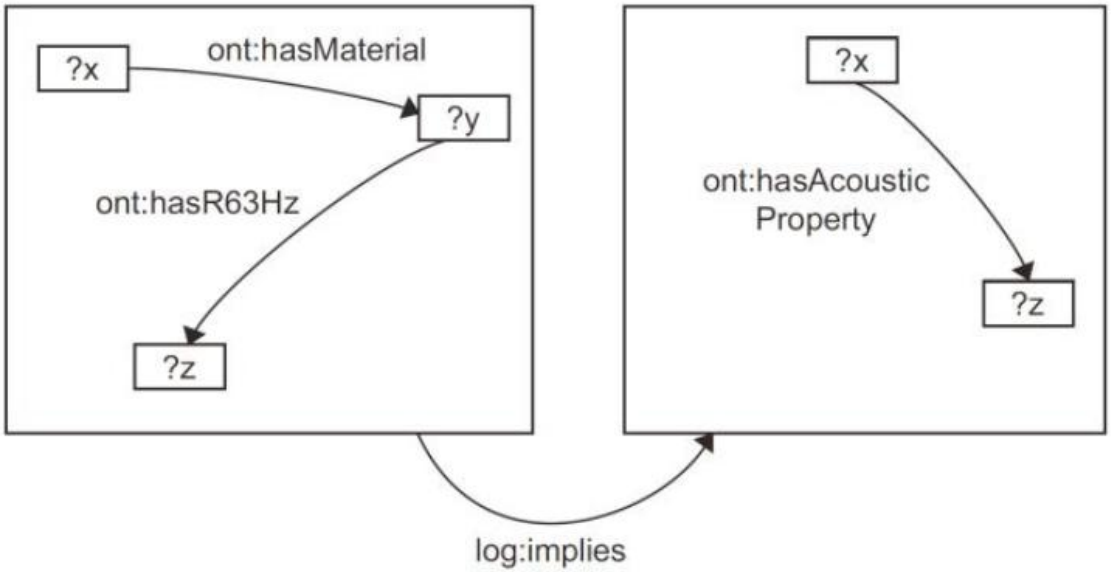


```
{
    ?x   ont:hasMaterial   ?y .
    ?y   ont:hasR63Hz   ?z
}
log:implies
{
    ?x   ont:hasAcousticProperty   ?z
}
```

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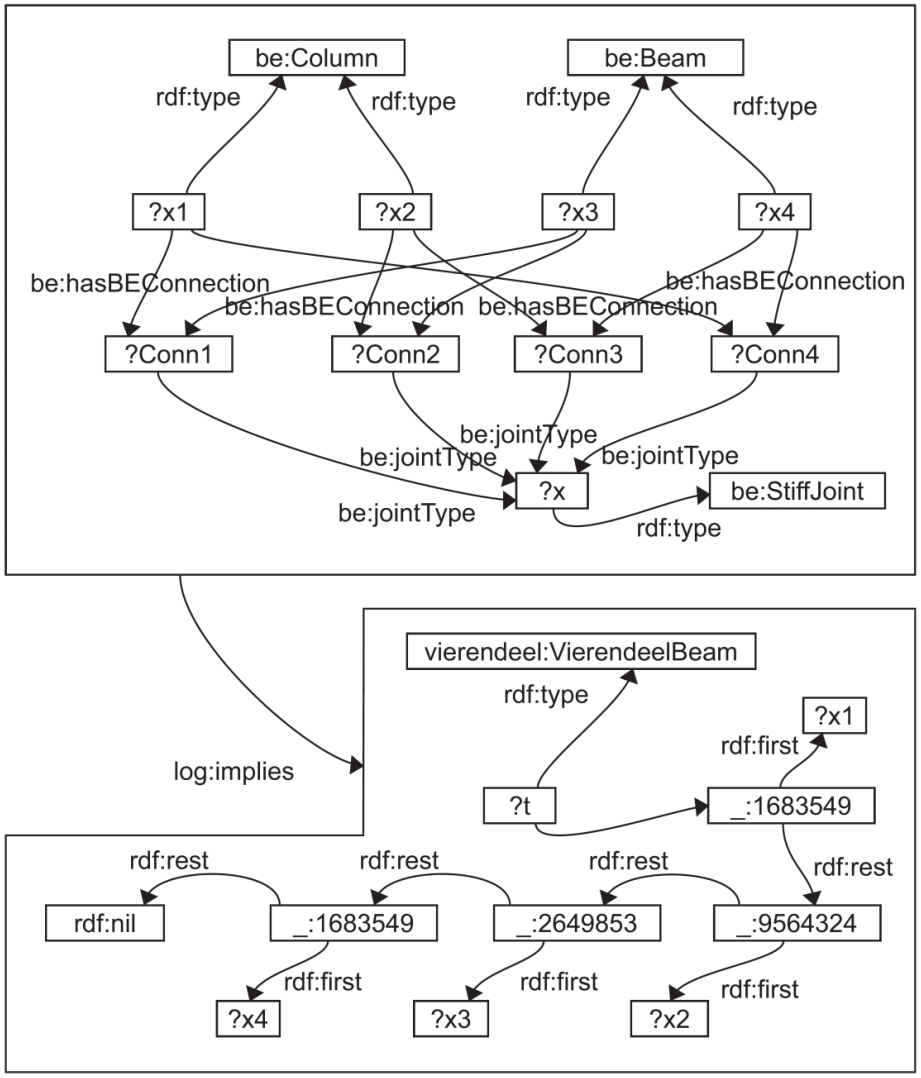
Converting standards into N3Logic

```
# Calculate R' [dB] for each Space surface that has a calculated Te,i value
{
  # Find relevant Space surface and their Te,i values
  ?SS a ifc:SpaceSurface.
  ?SS ifc:spaceBoundary [ifc:relatedBuildingElement [:acousticTau ?tau1]].
  (?SCOPE 1) e:findall
      (?tau {?SS ifc:spaceBoundary [ifc:relatedBuildingElement [:acousticTau ?tau]].} ?tauList).

  # Calculate R' [dB] for each Space surface
  ?tauList math:sum ?summedTau.
  (10 ?x) math:exponentiation ?summedTau.
  (-10 ?x) math:product ?R
}
=>
{?SS :acousticR ?R}.
```



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```
{
    ?BE   rdf:type   EN12354:BoundaryElement .
    ?BE   EN12354:elementSurfaceArea   ?a .
    ?BE   EN12354:partOfRoomBoundary   ?RB .
    ?RB   rdf:type   EN12354:RoomBoundary .
    ?RB   EN12354:facadeSurfaceArea   ?atot .
    ?BE   EN12354:soundReductionIndex_4000Hz   ?R_4000 .

    ?a   math:notLessThan   1 .

    (?a   ?atot)   math:quotient   ?value_i .
    (?R_4000   -10)   math:quotient   ?value_j .
    (10   ?value_j)   math:exponentiation   ?value_k .
    (?value_i   ?value_k)   math:product   ?value_l
}
log:implies
{
    ?BE   EN12354:directSoundPowerRatio_4000Hz   ?value_l
}
```

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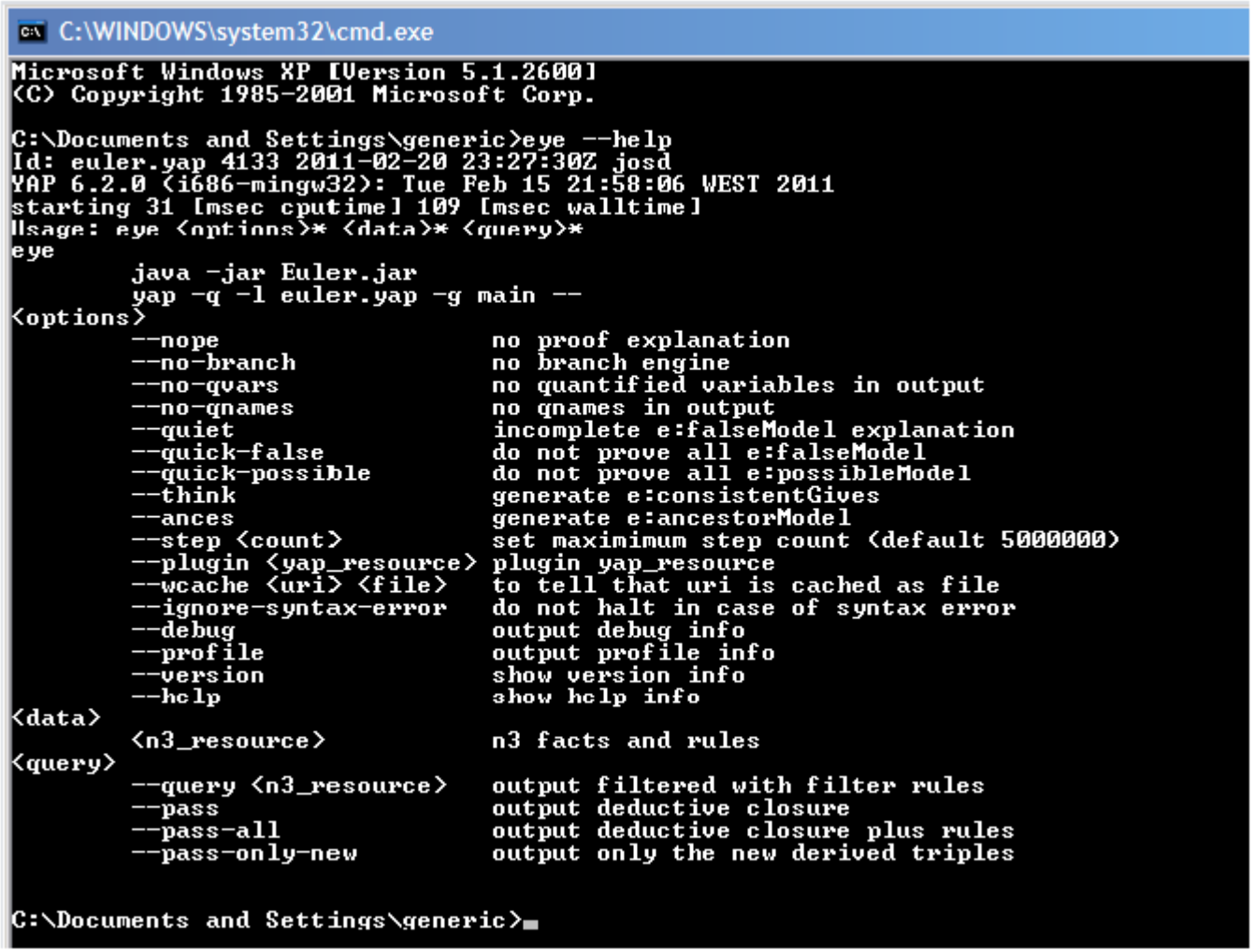
EYE reasoning engine



EYE command

eye --nope --quick-possible --quick-false
facts.n3 rules.n3 --query query.n3 > result.n3

```
#Processed by $Id: euler.yap 3098 2009-10-24 20:31:17Z josd $

@prefix : [...]

inst:RoomBoundary_1   NBNS014001:ComfortLevel   “normaal”^^xsd:string .
inst:RoomBoundary_2   NBNS014001:ComfortLevel   “verhoogd”^^xsd:string .
inst:RoomBoundary_3   NBNS014001:ComfortLevel   “normaal”^^xsd:string .
inst:RoomBoundary_4   NBNS014001:ComfortLevel   “normaal”^^xsd:string .


#ENDS 16 msec
#Trunk : 94/326 = 28.8343558282209 %
#Branch: 1/93 = 1.0752688172043 %
```

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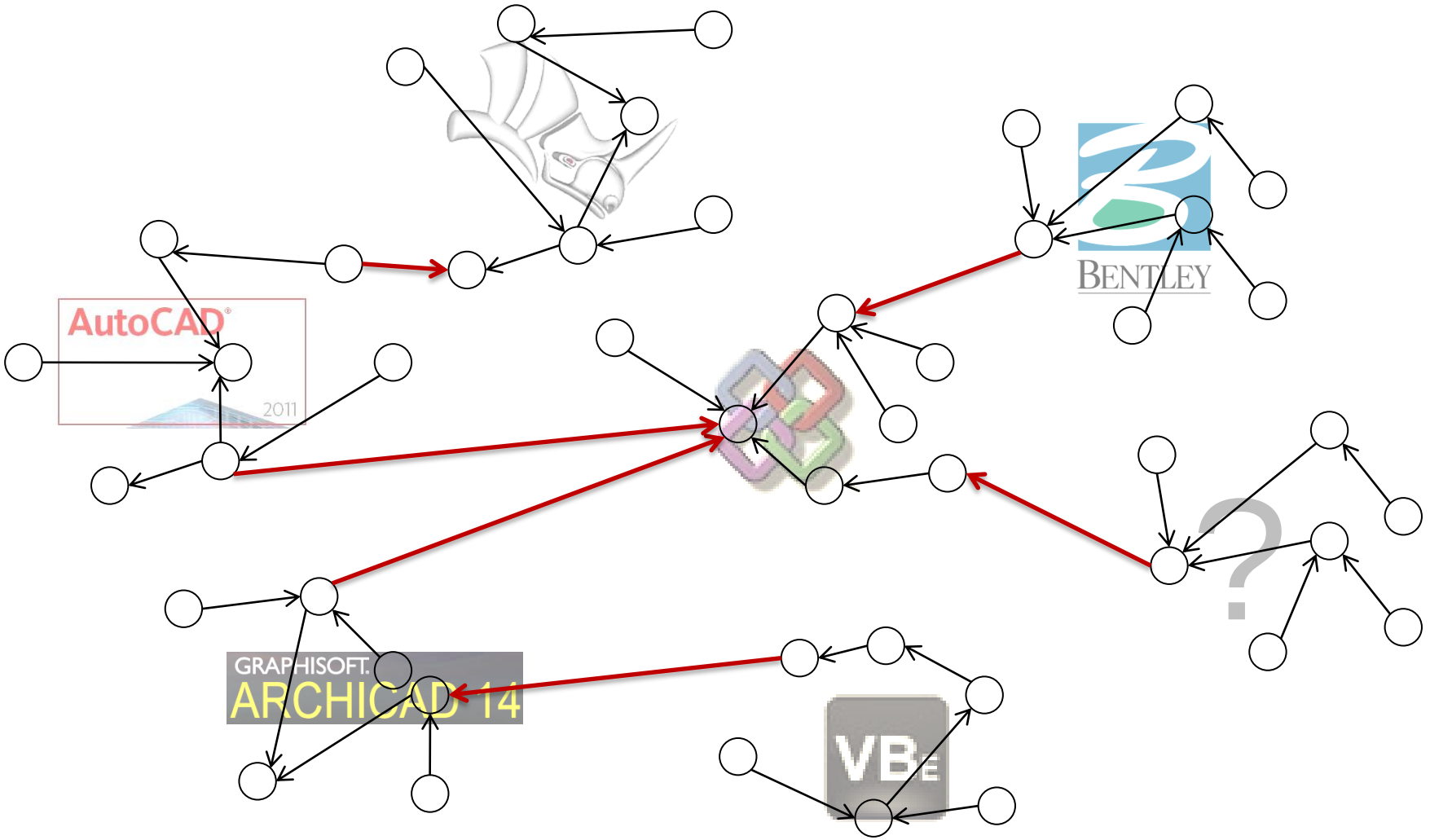
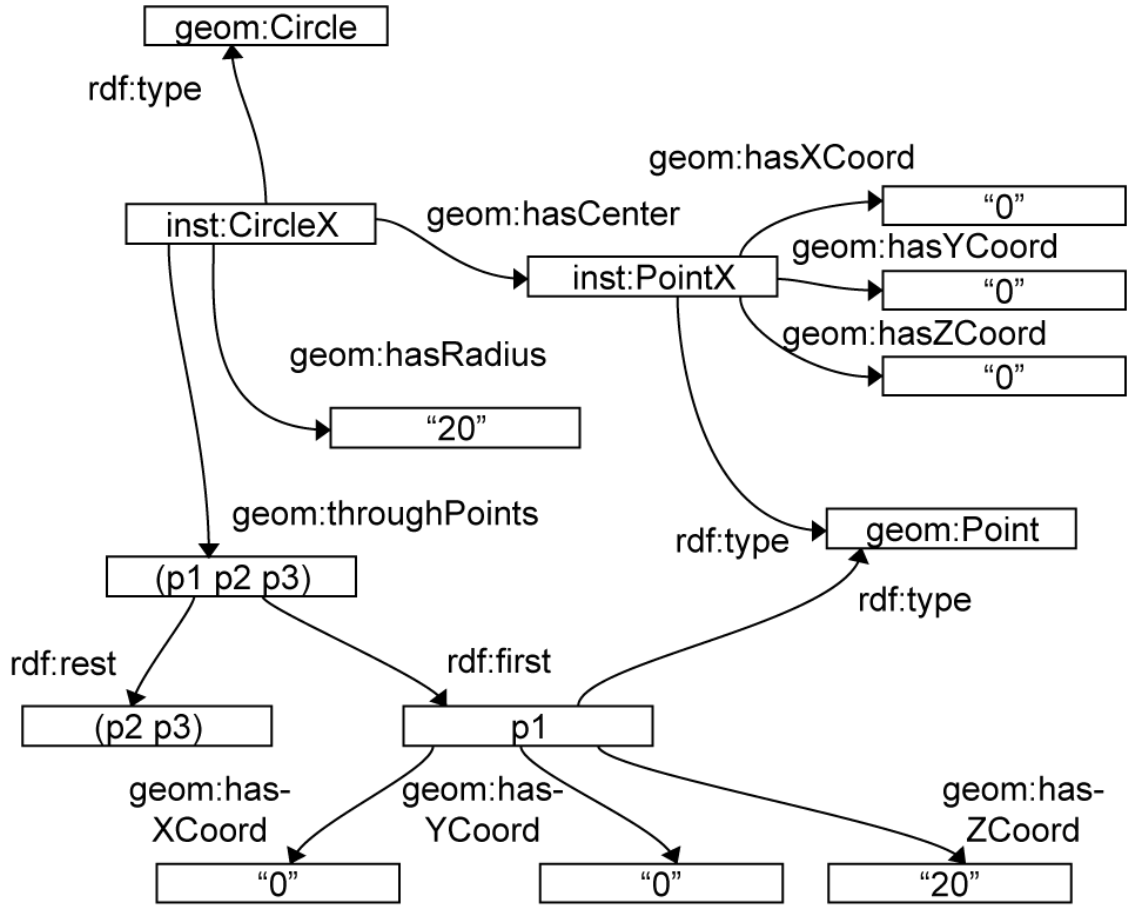
INTEROPERABILITY OF 3D INFORMATION

		DXF	DWG	FBX	OBJ	STL	DAE	VRML	X3D	U3D	3DS	STEP	IFC	GBXML	ACIS	PARASOLID	OPEN CASCADE
Mesh geometry	Mesh geometry	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Face normals			Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N		Y	Y
	Texture mapping vertices			Y	Y	N	Y	Y	Y	Y	Y		Y	N	N	N	Y
Freeform 3D	NURBS curve	Y	Y		Y	N	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y
	NURBS surface	*	*		Y	N	Y	N	Y	Y	N			N	Y	Y	Y
	Parameter space vertices	*	*		Y	N	Y	N	Y	Y	N			N	Y	Y	Y
	Trimming loops / holes	*	*		Y	N	N	N	Y	Y	N			N	Y	Y	Y
2D Primitives	Point	Y	Y		N	N	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y
	Arc2D	Y	Y		N	N	N	N	Y	N	N		N	N		N	Y
	ArcClose2D	N	N		N	N	N	N	Y	N	N		N	N		N	N
	Circle2D	Y	Y		N	N	Y	N	Y	N	N		Y	N		Y	Y
	Disk2D	N	N		N	N	N	N	Y	N	N		N	N		N	N
	Ellipse2D	Y	Y		N	N	Y	N	N	N	N		Y	N		N	Y
	Polyline2D	Y	Y		N	N	N	N	Y	N	N		Y	N		N	Y
	Polypoint2D	N	N		N	N	N	N	Y	N	N		N	N		N	Y
	Rectangle2D	N	N		N	N	N	N	Y	N	N		Y	N		N	Y
	Triangleset2D	N	N		N	N	N	N	Y	N	N		N	N		N	Y
	Hyperbola	N	N		N	N	Y	N	N	N	N		Y	N		N	Y
	Parabola	N	N		N	N	Y	N	N	N	N		Y	N		N	Y
3D Primitives	Box	*	*		N	N	N	Y	Y	N	N		N	N		N	Y
	Cone	*	*		N	N	Y	Y	Y	N	N		Y	N	Y	Y	Y
	Cylinder	*	*		N	N	Y	Y	Y	N	N		Y	N	Y	Y	Y
	Sphere	*	*		N	N	Y	Y	Y	N	N		Y	N		Y	Y
	Torus	*	*		N	N	Y	N	N	N	N		N	N		Y	Y
	Polyline3D	Y	Y		N	N	N	Y	Y	N	N		Y	N		N	N
	Helix	Y	Y		N	N	N	N	N	N	N		N	N		N	N
Geometric features	Basic feature transformations (scale, rotate, etc.)	*	*		N	N	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y
	Surface modelling (sweep, revolve, etc.)	*	*		N	N	Y	N	Y	N	N	Y	Y	N	Y	Y	Y
	Boolean operations	*	*		N	N	N	N	N	N	N	Y	Y	N	Y	Y	Y

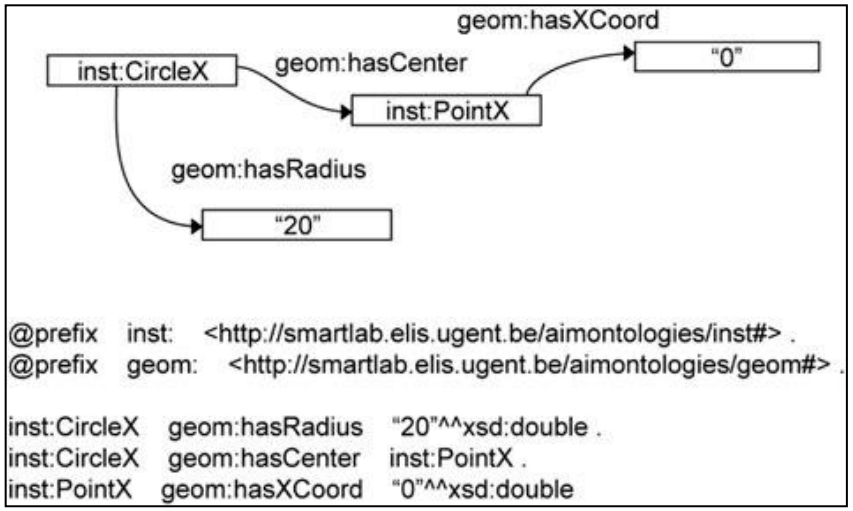
Possible enhancements through a semantic web approach





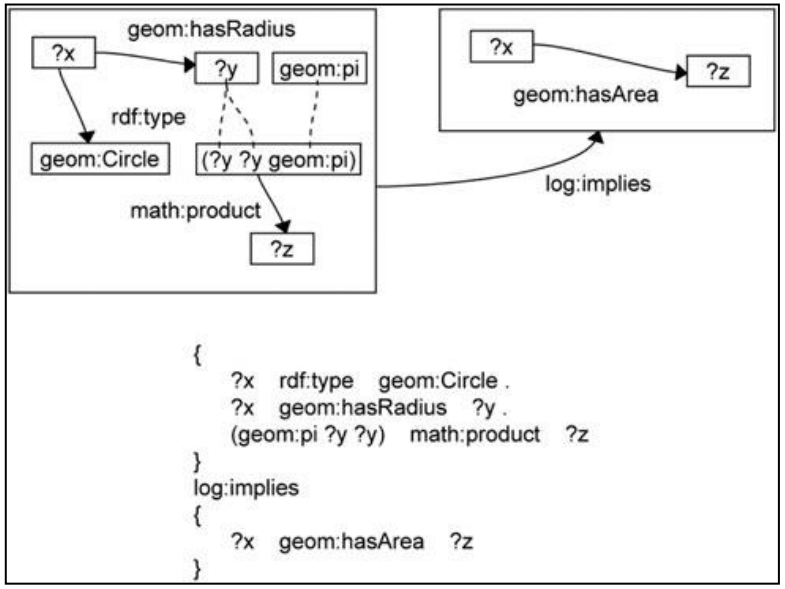
[5] P. Pauwels, D. Van Deursen, J. De Roo, T. Van Ackere, R. De Meyer, R. Van de Walle, J. Van Campenhout. Three-dimensional information exchange over the semantic web for the domain of architecture, engineering, and construction. Artificial Intelligence for Engineering Design, Analysis and Manufacturing 25 (4) 2011, 317-332.

RDF



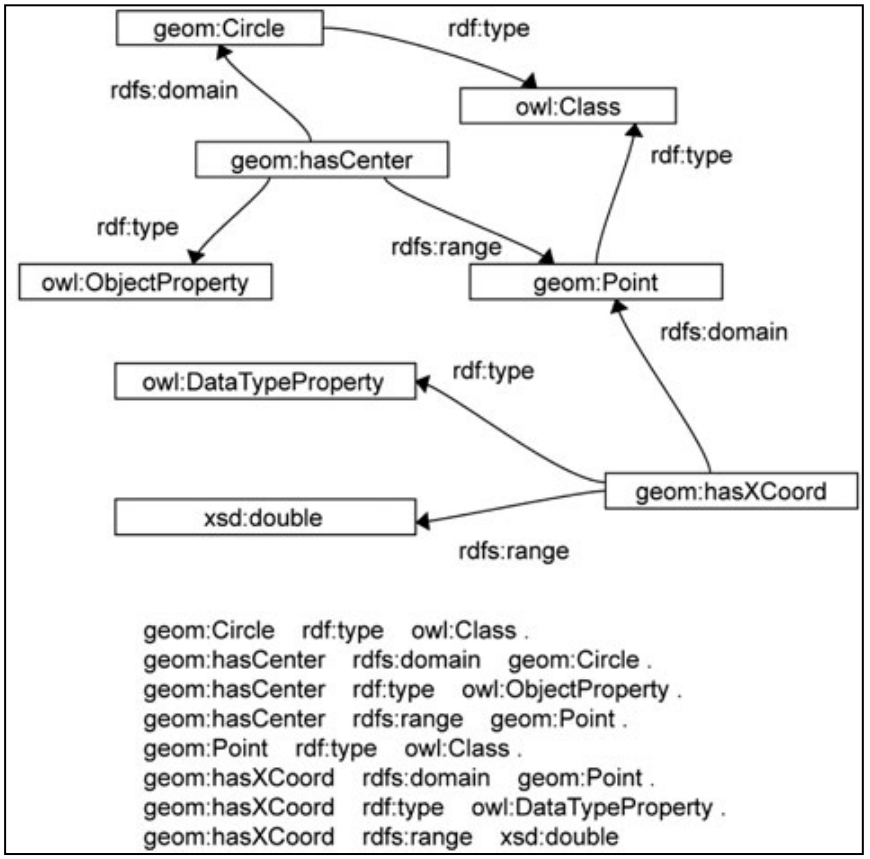

```
@prefix  inst:  <http://smartlab.elis.ugent.be/aimontologies/inst#> .
@prefix  geom:  <http://smartlab.elis.ugent.be/aimontologies/geom#> .

inst:CircleX  geom:hasRadius  "20"^^xsd:double .
inst:CircleX  geom:hasCenter  inst:PointX .
inst:PointX   geom:hasXCoord  "0"^^xsd:double
```



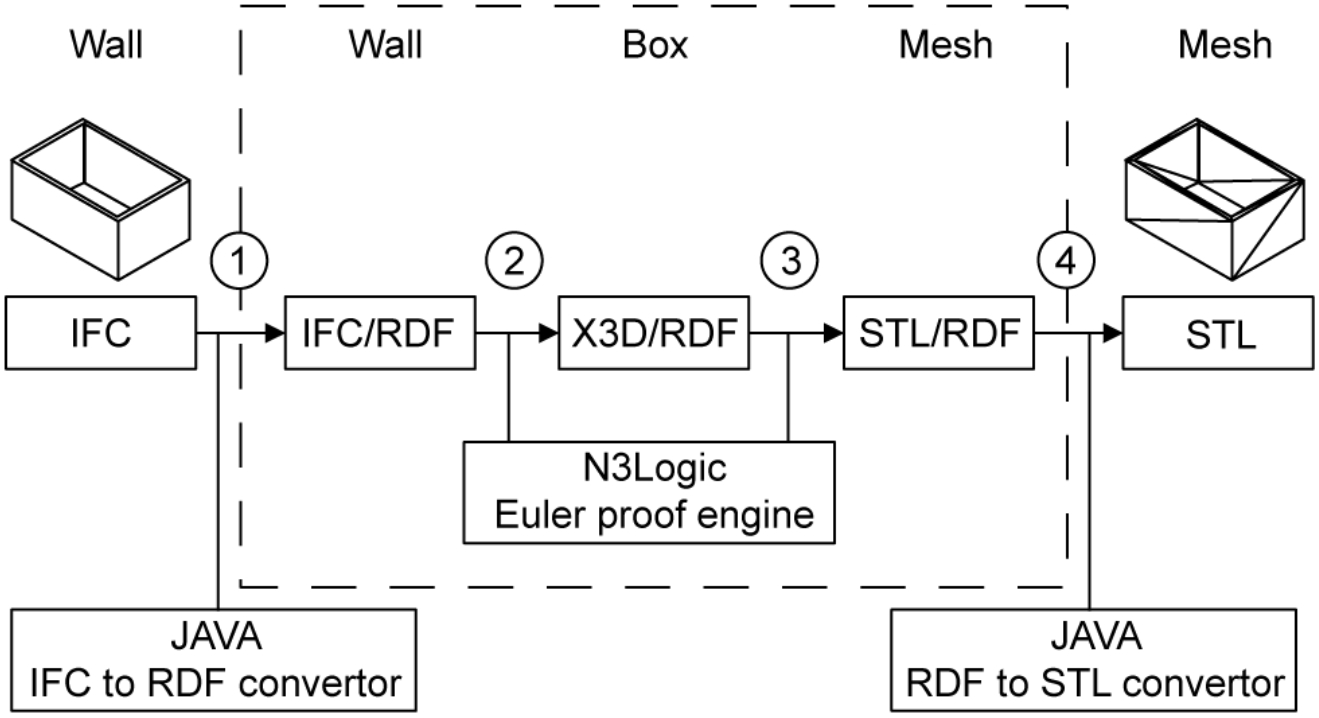

```
{
    ?x  rdf:type  geom:Circle .
    ?x  geom:hasRadius  ?y .
    (geom:pi ?y ?y)  math:product  ?z
}
log:implies
{
    ?x  geom:hasArea  ?z
}
```

N3Logic




```
geom:Circle  rdf:type  owl:Class .
geom:hasCenter  rdfs:domain  geom:Circle .
geom:hasCenter  rdf:type  owl:ObjectProperty .
geom:hasCenter  rdfs:range  geom:Point .
geom:Point  rdf:type  owl:Class .
geom:hasXCoord  rdfs:domain  geom:Point .
geom:hasXCoord  rdf:type  owl:DataTypeProperty .
geom:hasXCoord  rdfs:range  xsd:double
```

OWL



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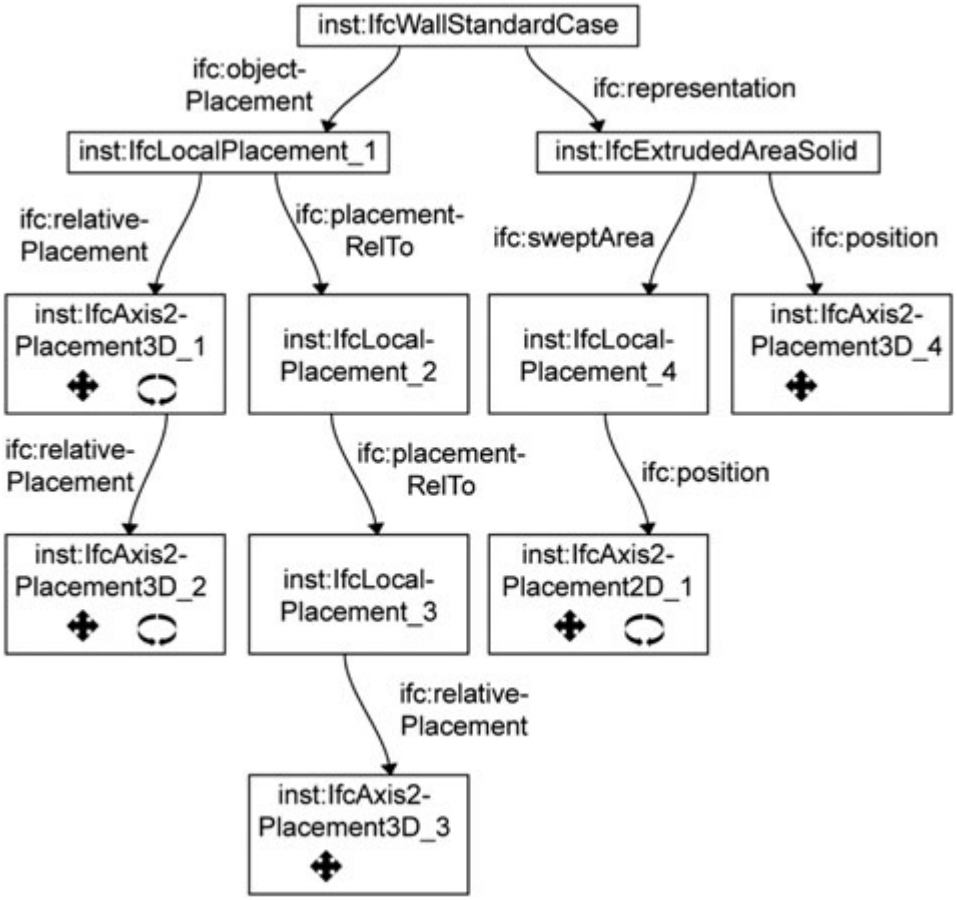

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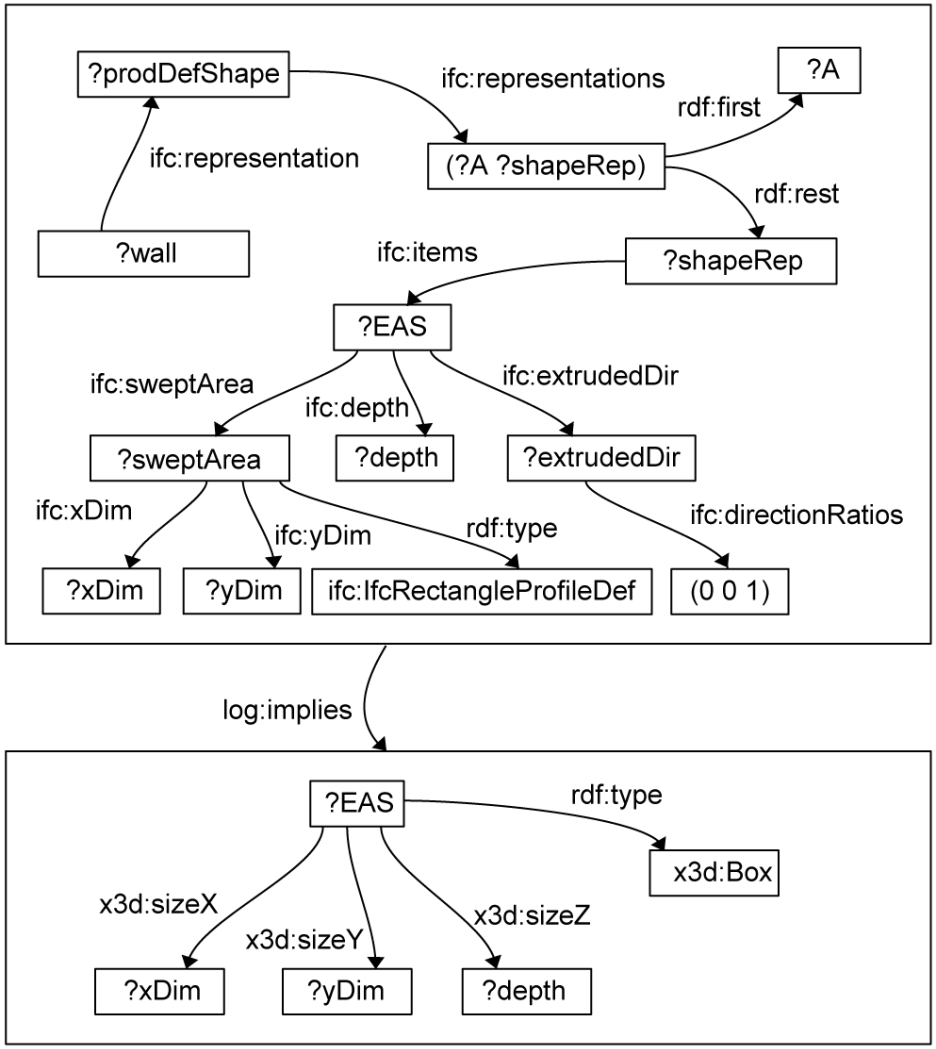

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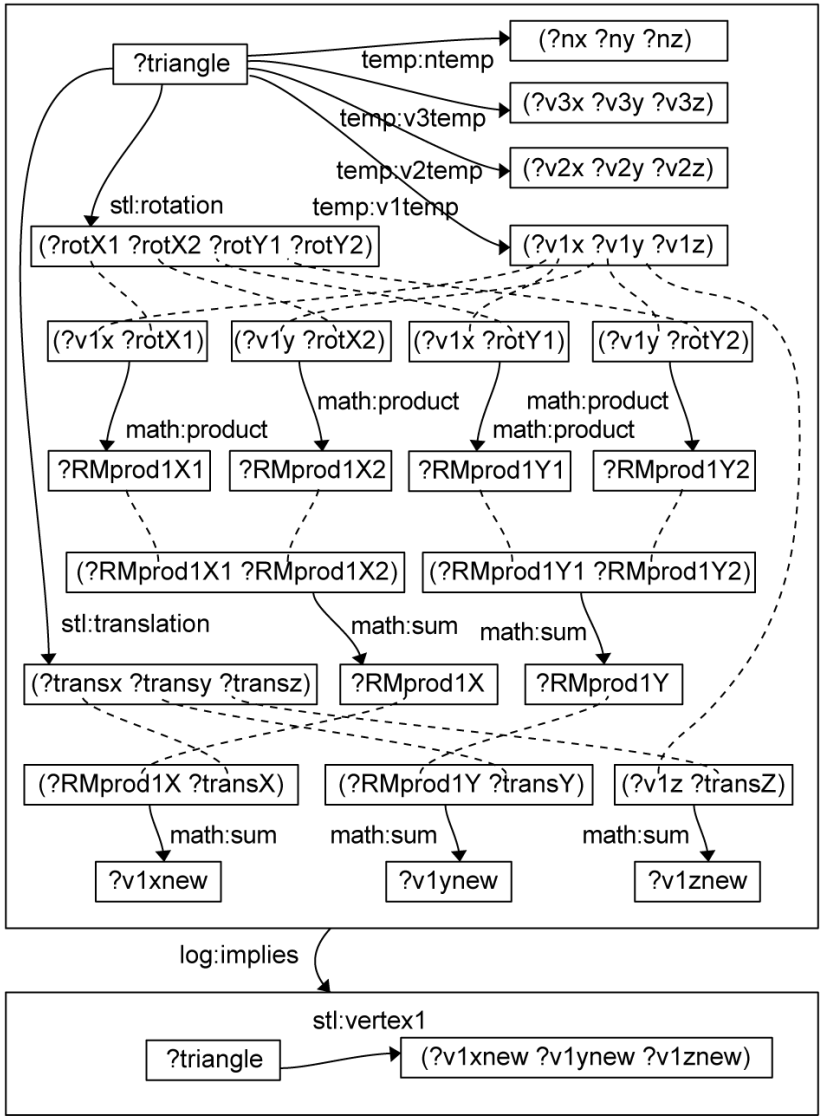

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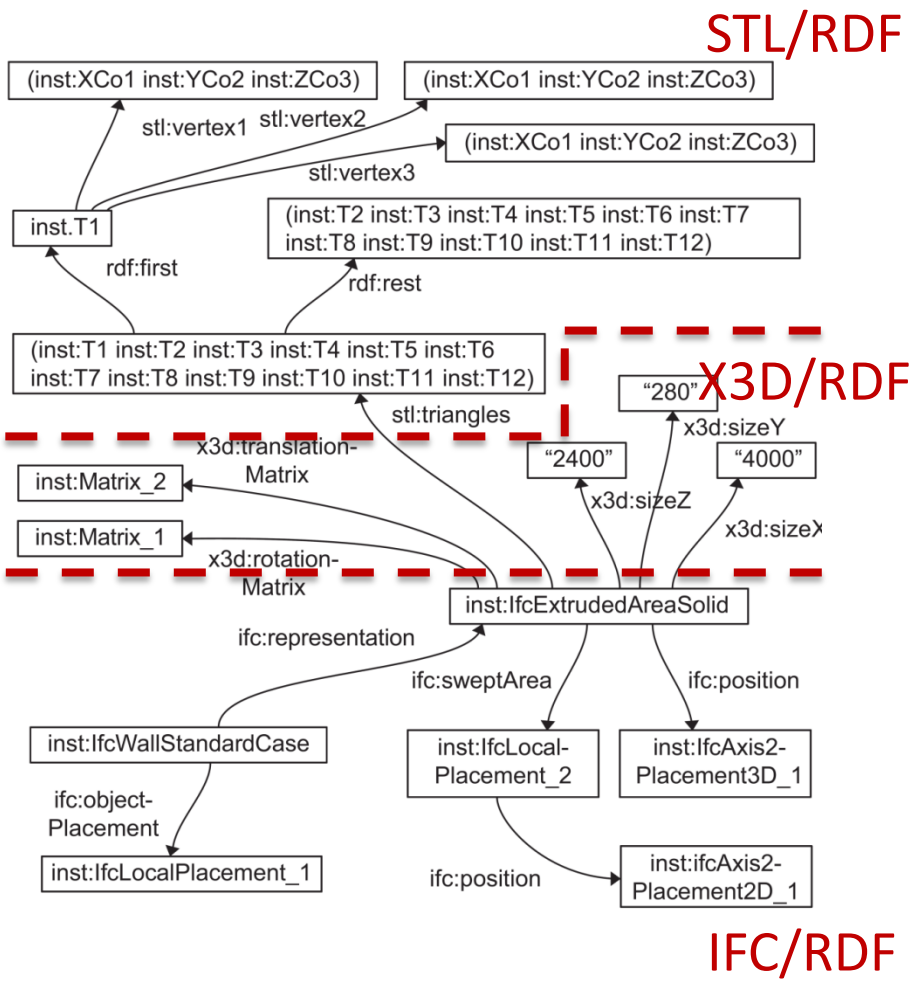

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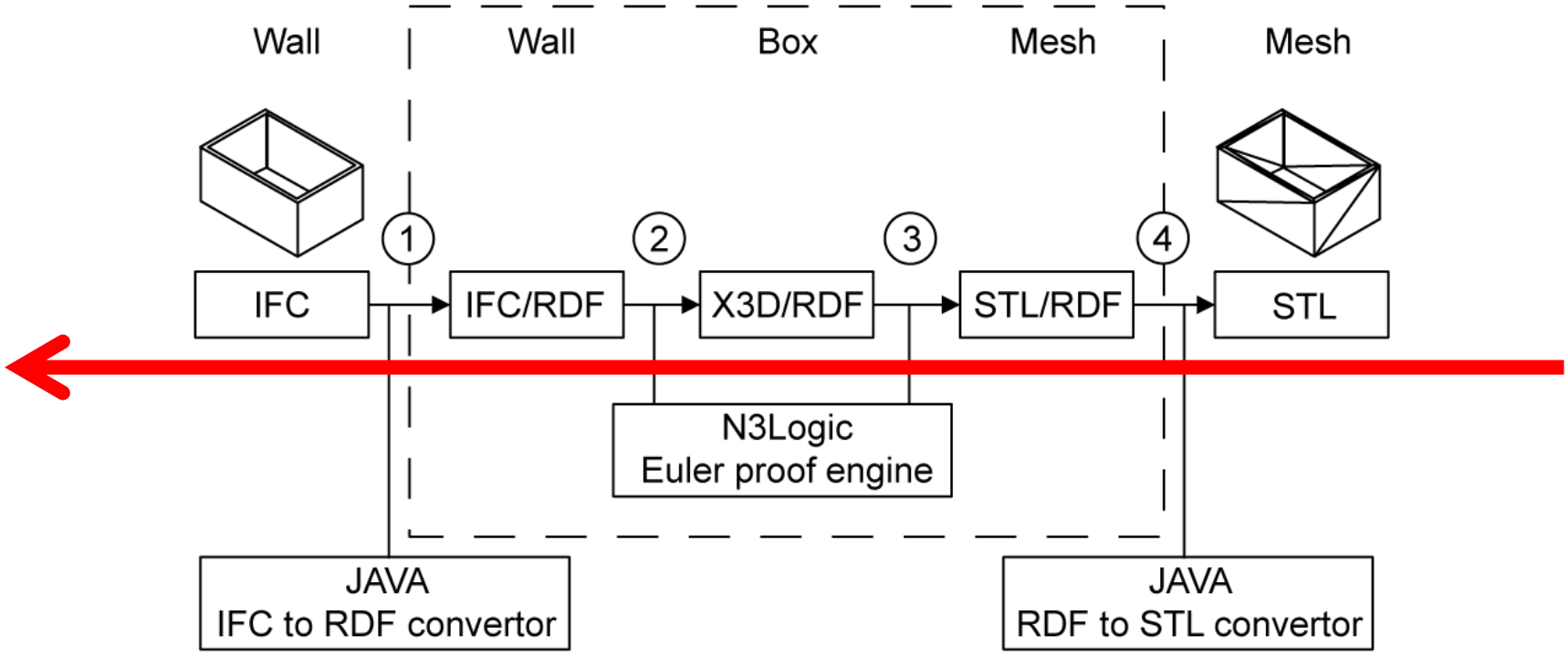

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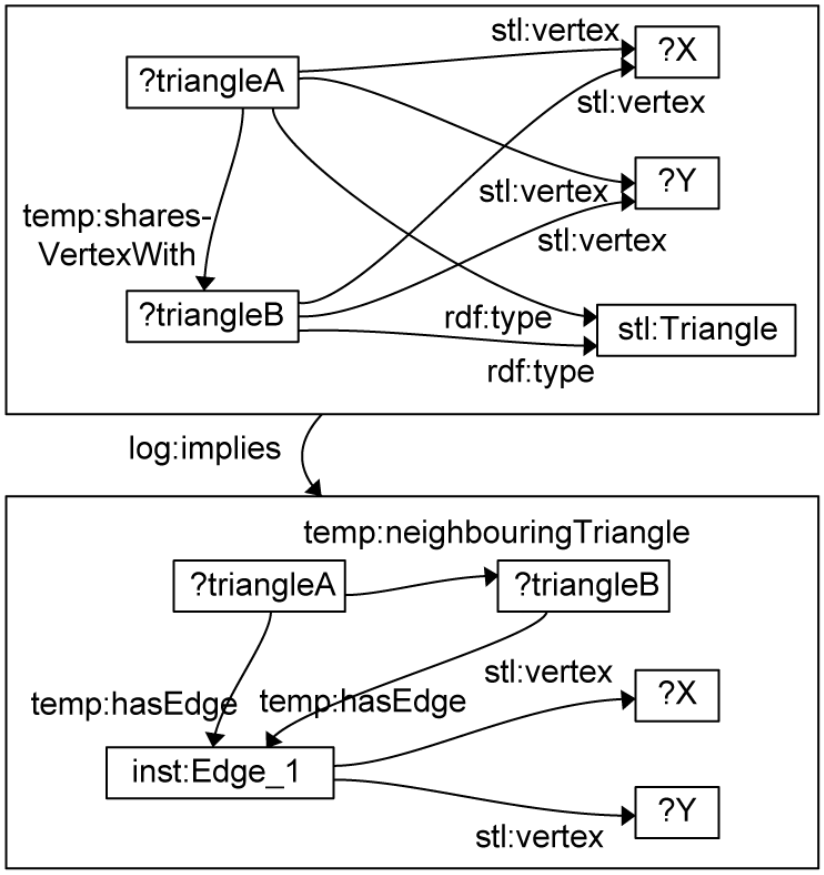

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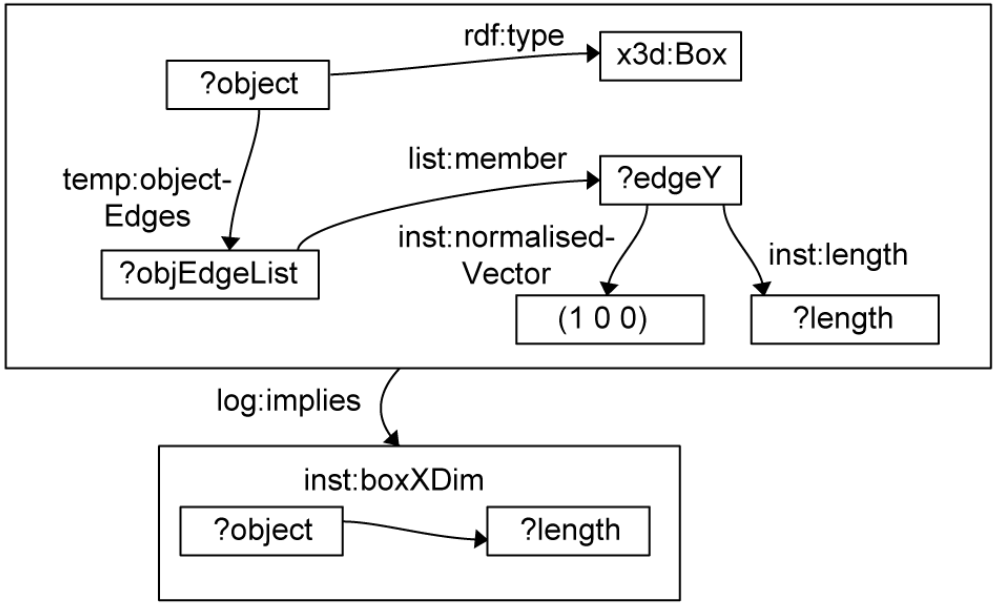

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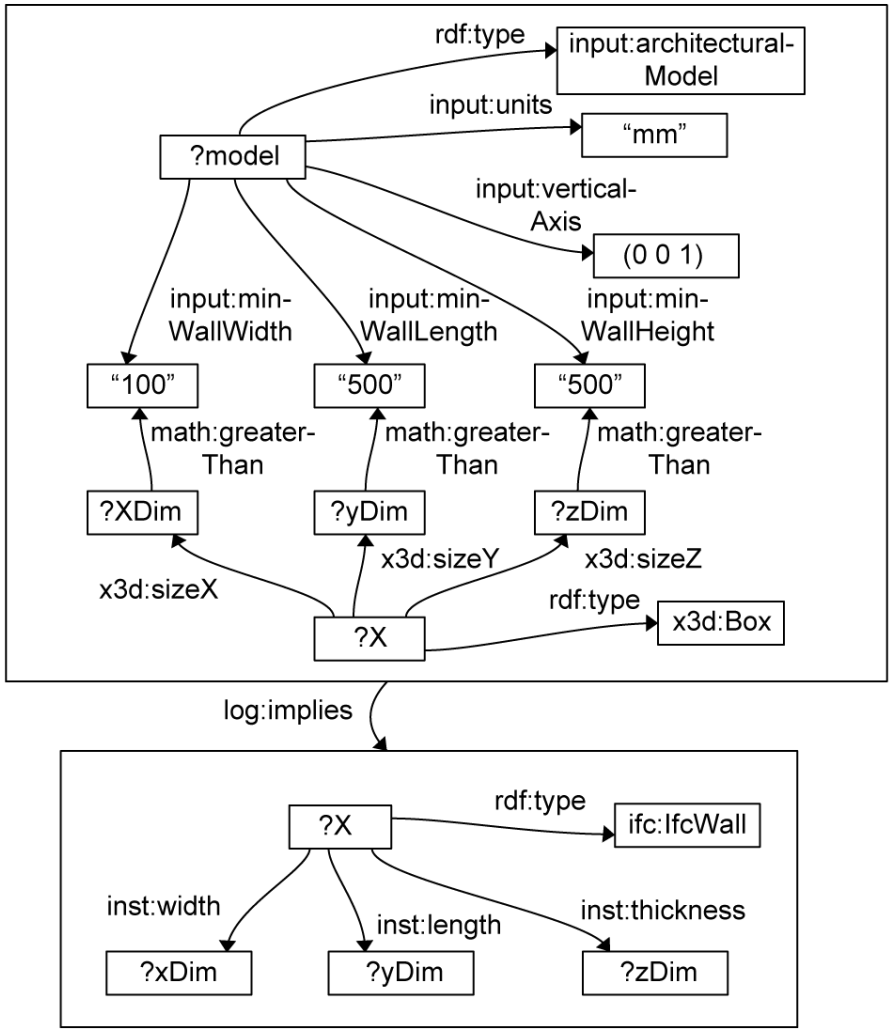

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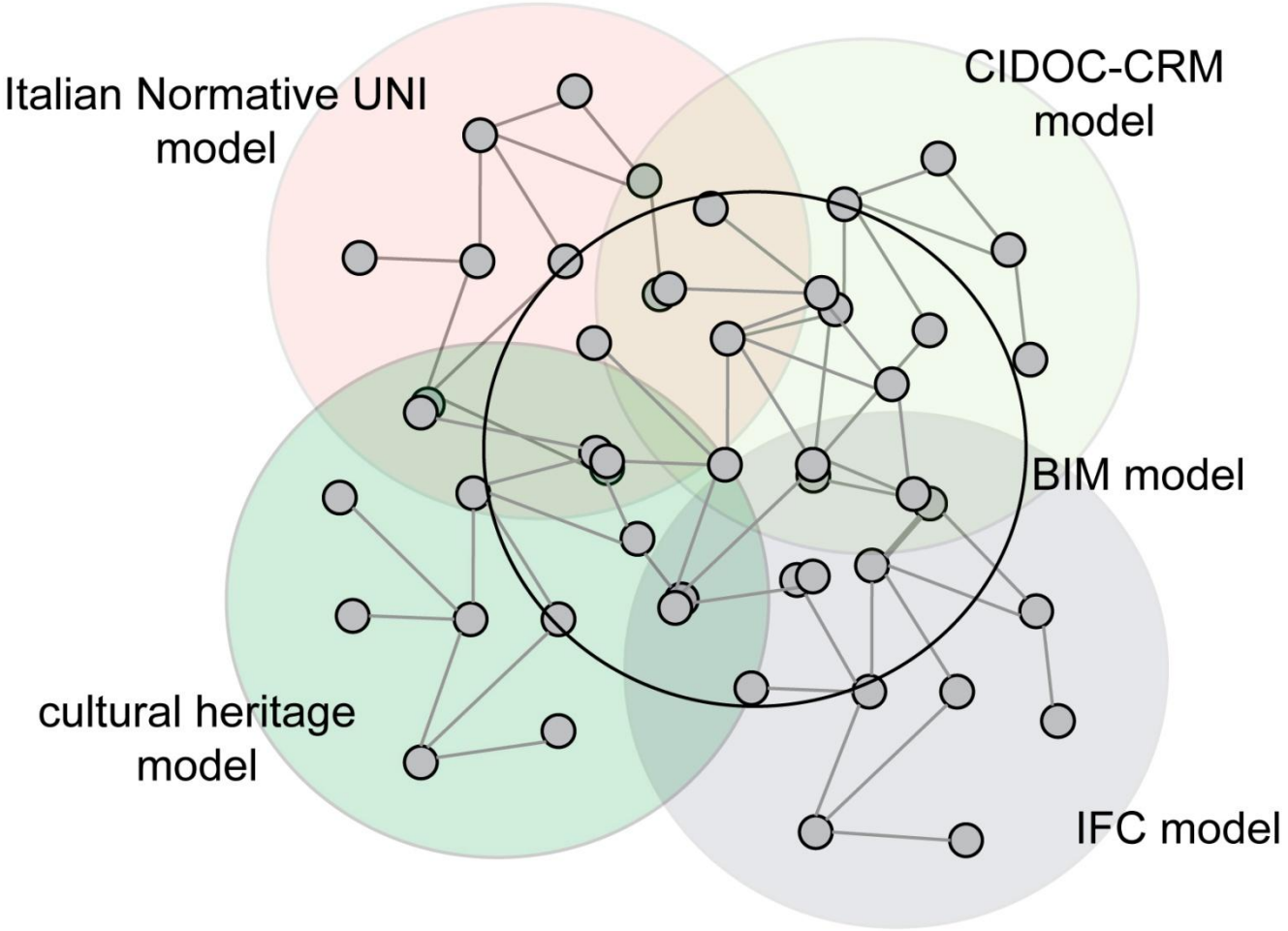
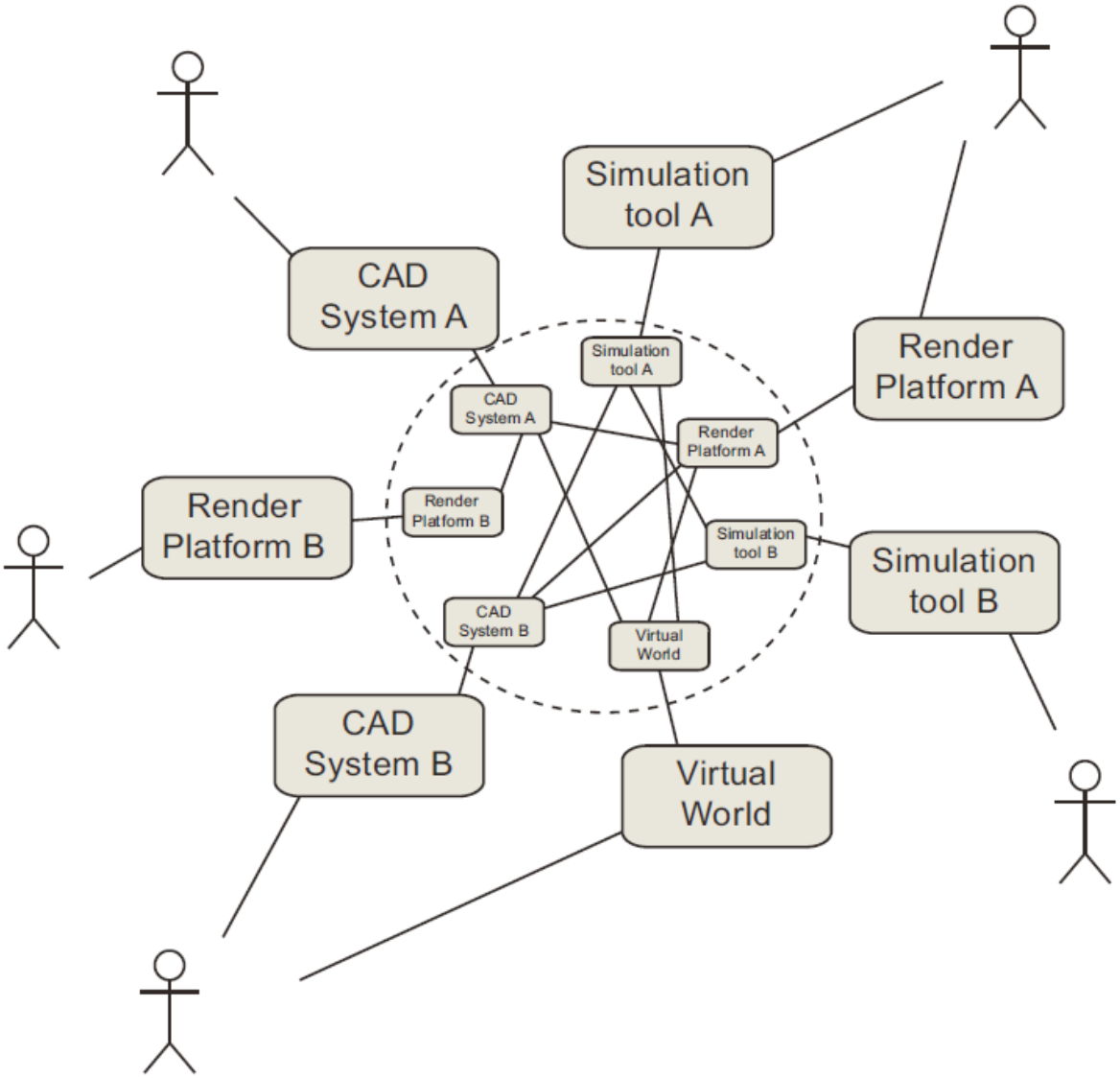
How to integrate diverse information models, in particular those that describe the same information differently???




Simulation tool A
CAD System A
Render Platform A
Render Platform B
Simulation tool B
CAD System B
Virtual World
Simulation tool A
CAD System A
Render Platform A
Render Platform B
Simulation tool B
CAD System B
Virtual World