

A story of an initiative to extend the X3D Cadprofile adding BREP solid representation

An issue of semantic vs. structural expression

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What about ?

- A story happened in 2007 at Electricité de France,
 - that is a large Utility involved in energy production, transport and distribution of electricity,
 - that is designer of its own nuclear, thermal, hydraulic, power plants,
 - that use CAD technology for a long time, (started in the end of seventies),
 - Schematic System design,
 - AEC mock-up,
 - Equipments and concrete buildings CAD design.
 - that has a long experience on all kind of computation based on 3D models.

Which issues ?

- A question came during a discussion with a leader at EDF :
 - I know that you were involved in CAD domain sometime ago, didn't you ?.
 - Yes, but it was a very long time ago...
 - Well, we have a problem of "CAD" with our multiphysics computing platform . Could you help us ?
 - Ah, maybe. What is it?
 - "The modeler of our platform is really just a data integrator before meshing. It has not the ergonomic features of a real CAD software. Users prefer to use other softwares they use for other purposes. Retrieving data from these other sources is a recurring problem ".
 - Do you use any standard exchange?
 - Yes, for some we use STEP, and CSG, but that does not work very well. Models need often to be fixed... for some sources we have to use specific converters. All this is expensive to maintain ...
 - And for output?
 - For output we look at X3D as a language for results publication.
 - May be you can use it for input as well, don't you ?

Then...

Then one of the domain experts came to me:

- You mentioned the idea of using X3D to express CAD data :
do you know that there is expected a "CAD profile" in the standard ?
But it is very incomplete.
I have some ideas to introduce the description of BREP solids.
Could we study this together?
- Why not ? To work on BREP is a good idea, as we might also describe
solid convolutions in CSG trees.
- We need to take care of BREP first. Then we will look to CSG trees.
- OK. I propose to do that through a kind of modelling interview.
I have some new ideas of methodology to manage that.

To old questions try new approaches

- In my past, after a long time in an engineering company,
I worked at EDF on the design of 3D CAD systems,
then I was pragmatically concerned with 2D CAD Schematic, that were
more important for plant engineering,
Then, logically I went back down to 1D CAD, (as to my experience Word® is
the most used CAD software in industrial engineering !)
Finally the aim of all this was similarly to reduce the entropy of
descriptions.
Then again, from Document structuration (SGML and XML)
I switched to the study of the used terminologies
and then to thesaurus,
and then to formal ontologies...
The study of formal ontologies, because of their description
efficiency, led me to rethink everything I've studied, and many
other things.

So...

- We started to formalize our formal BREP model as an OWL ontology. In order to do it, we recorded our conversation via a popular rdf editor.
 - What is (a BREP) ?
 - We need to look at its components :
 - A BREP is a solid, that has a shell... what are solid and shell ?
 - A shell has edges... what is an edge ?
 - An edge has vertex... what is a vertex ?
 - A shell has faces... what is a face ?
 - A face has a loop... what is a loop ?
 - (...)
- ... so we went to a complete consistent description, committed we were to let nothing implicit.

Two kind of solids : BREP and CSG

Conception : Henry Boccon-Gibod

Ontologie : X3D CAD Profile ontologic study
élément : owl:Class
rdf:ID : Solid_Class
rdfs:label : Solid

rdfs:comment : *A solid is a 3D body. It can be either defined by its boundaries (Brep definition) or by boolean operations (CSG). It is an abstract class to allow future CSG extensions.*
Solid : Body{}

index

```
graph LR; Body((Body)) --- Solid((Solid)); Solid --- BrepSolid((BrepSolid)); Solid --- CSGSolid((CSG Solid));
```


BREP Solid has a shell...

Conception : Henry Boccon-Gibod

Mozilla Firefox

file:///home/henry/Tools/Projects/X3D-CAD/OutputData/X3D-CAD/BrepSolid_Class.svg

Ontologie : X3D CAD Profile ontologic study
élément : owl:Class
rdf:ID : BrepSolid_Class
rdfs:label : BrepSolid

rdfs:comment : A BrepSolid is a Solid defined by its boundaries.
Its boundaries are sets of shells.
The outer shell encloses all the other shells. Holes can be defined in a body by defining inner shells.
The orientation of a shell is given by the orientation of its normal : a point is inside a shell if the first intersection of any ray starting from this point with the shell is oriented in the same direction as the normal of this shell.
A boolean swapNormal is provided so that the whole sheet can be swapped.
The shells in a body are not allowed to intersect each-other or to self-intersect (manifold).
BrepSolid : Solid {
 MFShell brepSolidShell
 MFBool swapNormal
}

index

Diagram illustrating the BrepSolid structure:

- Solid** (yellow circle) is connected to **BrepSolid** (yellow circle).
- BrepSolid** is connected to **Shell** (yellow circle).
- Shell** is connected to **Pipe** (red diamond).
- Shell** is connected to **Normal** (blue square).
- Normal** is connected to **Boolean** (blue square).
- Boolean** is connected to **SwapNormal** (blue square).

Annotations:

- Normal** is labeled ≤ 1 true Normal.
- Boolean** is labeled <http://www.w3.org/2001/XMLSchema#boolean>.
- SwapNormal** is labeled **SwapNormal**.

Shell has faces...

Mozilla Firefox

file:///home/henry/Tools/Projects/X3D-CAD/OutputData/X3D-CAD/Shell_Class.svg

Ontologie : X3D CAD Profile ontologic study
élément : owl:Class
rdf:ID : Shell_Class
rdfs:label : Shell

rdfs:comment : A shell is a collection of Faces. The normal of each face can be swapped so that the normals are consistent. If the shell is part of a BrepSolid, all the faces must have a consistent normal, and no self-intersection is allowed. The topology of the shell must also be enforced. To do this, a set of Edge and Vertex Topology is provided.

Shell{
 MFFace face
 MFBool swapNormal
}

index

Conception : Henry Boccon-Gibod

Shell

- Chose
- BrepSolid
 - brep solid shell
- Sheet
 - ≤ 1 sheet Shell
- ≤ 1 true Normal
 - http://www.w3.org/2001/XMLSchema#boolean
- shell Faces
 - Face
- Skin

Faces may be BREP or meshed...

Conception : Henry Boccon-Gibod

Ontologie : X3D CAD Profile ontologic study
élément : owl:Class
rdf:ID : Face_Class
rdfs:label : Face

rdfs:comment : A Face is a part of a shell.
A Face can be defined by a surface and contours (Brep definition). It can also be defined by a mesh if no analytical description is available.
Face{}

index

≤ 1 true Normal
<http://www.w3.org/2001/XMLSchema#boolean>

"Chose"

Shell

Face

BrepFace

Meshed Face

shell Faces

BREP faces has surface and loop...

Conception : Henry Boccon-Gibod

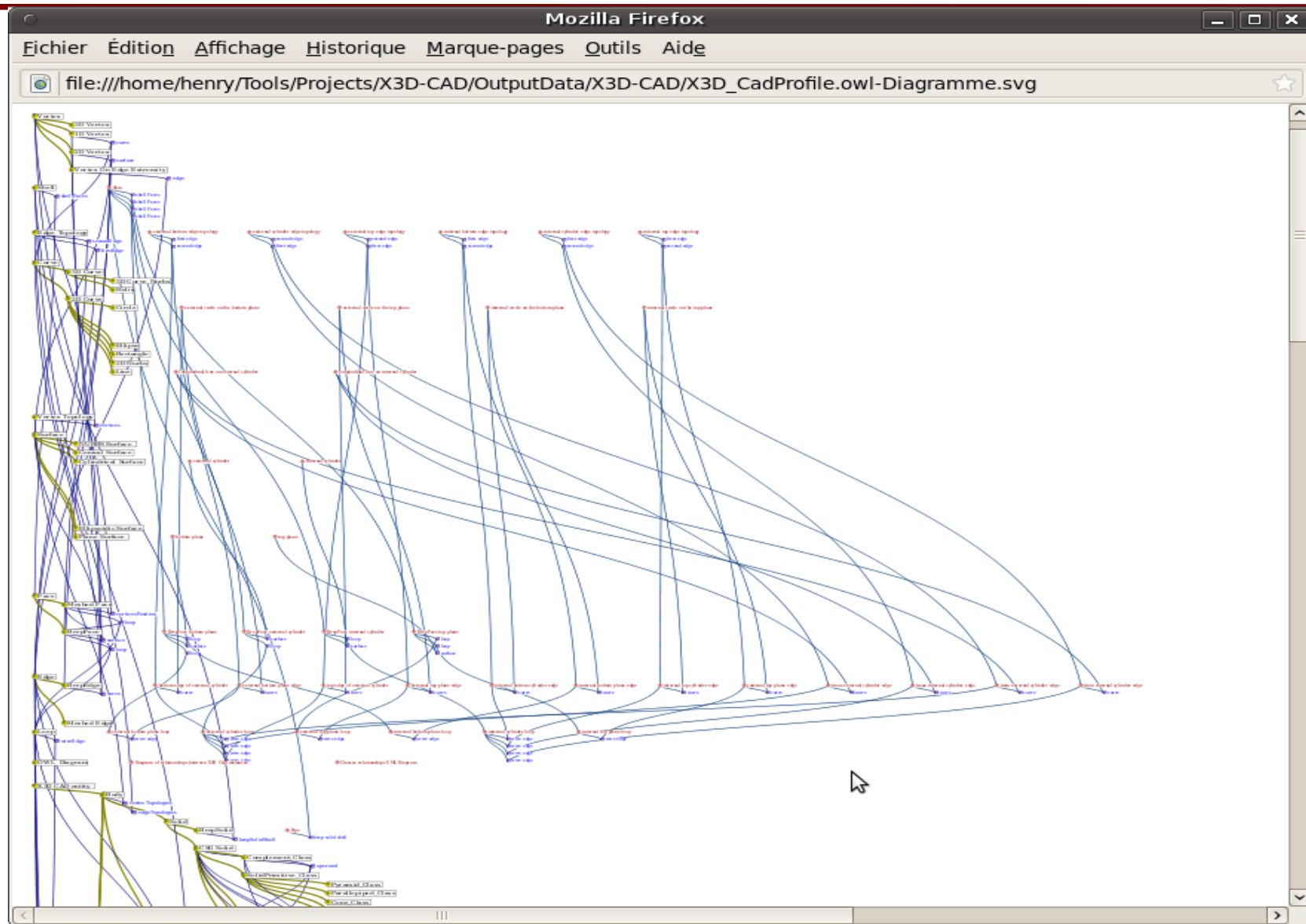
Ontologie : X3D CAD Profile ontologic study
élément : owl:Class
rdf:ID : BrepFace_Class
rdfs:label : BrepFace

rdfs:comment : A BrepFace is given by a Surface defined by an equation $(x, y, z) = S(u, v)$ that can be implicit and a set of Loops. The direction of the loop tells if the space within is included or excluded from the surface : points inside a counter-clock loop are part of a face. The loops of a face are not allowed to intersect each other.
BrepFace : Face{
 Surface surface
 MFLoop loop
}

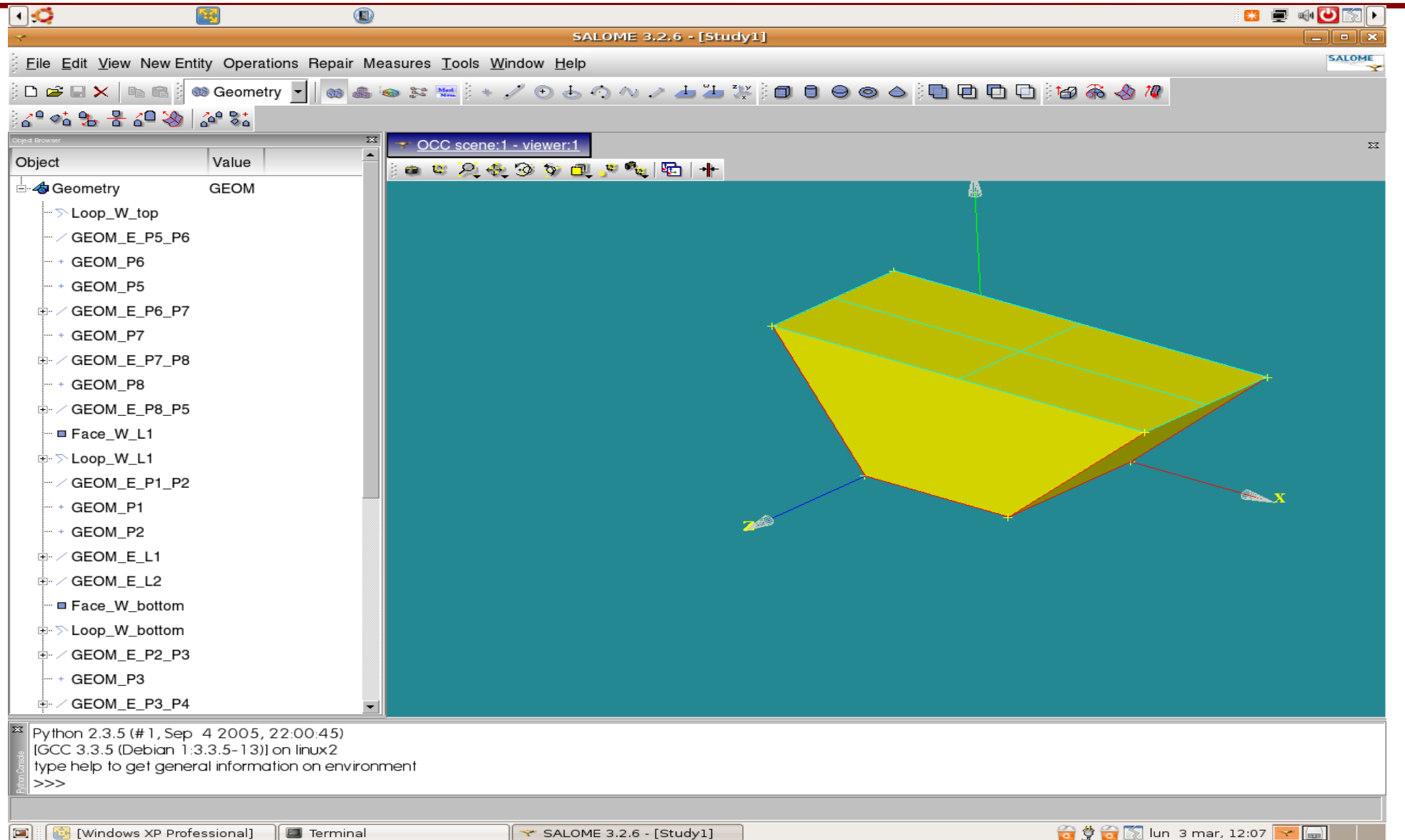
index

```
graph LR; Face((Face)) --- BrepFace((BrepFace)); BrepFace --- S1["≤ 1 surface"]; S1 --- Surface((Surface)); BrepFace --- loop(loop); loop --- Loop((Loop)); BrepFace --- B1["BrepFace bottom plane"]; BrepFace --- B2["BrepFace external cylinder"]; BrepFace --- B3["BrepFace internal cylinder"]; BrepFace --- B4["BrepFace top plane"];
```

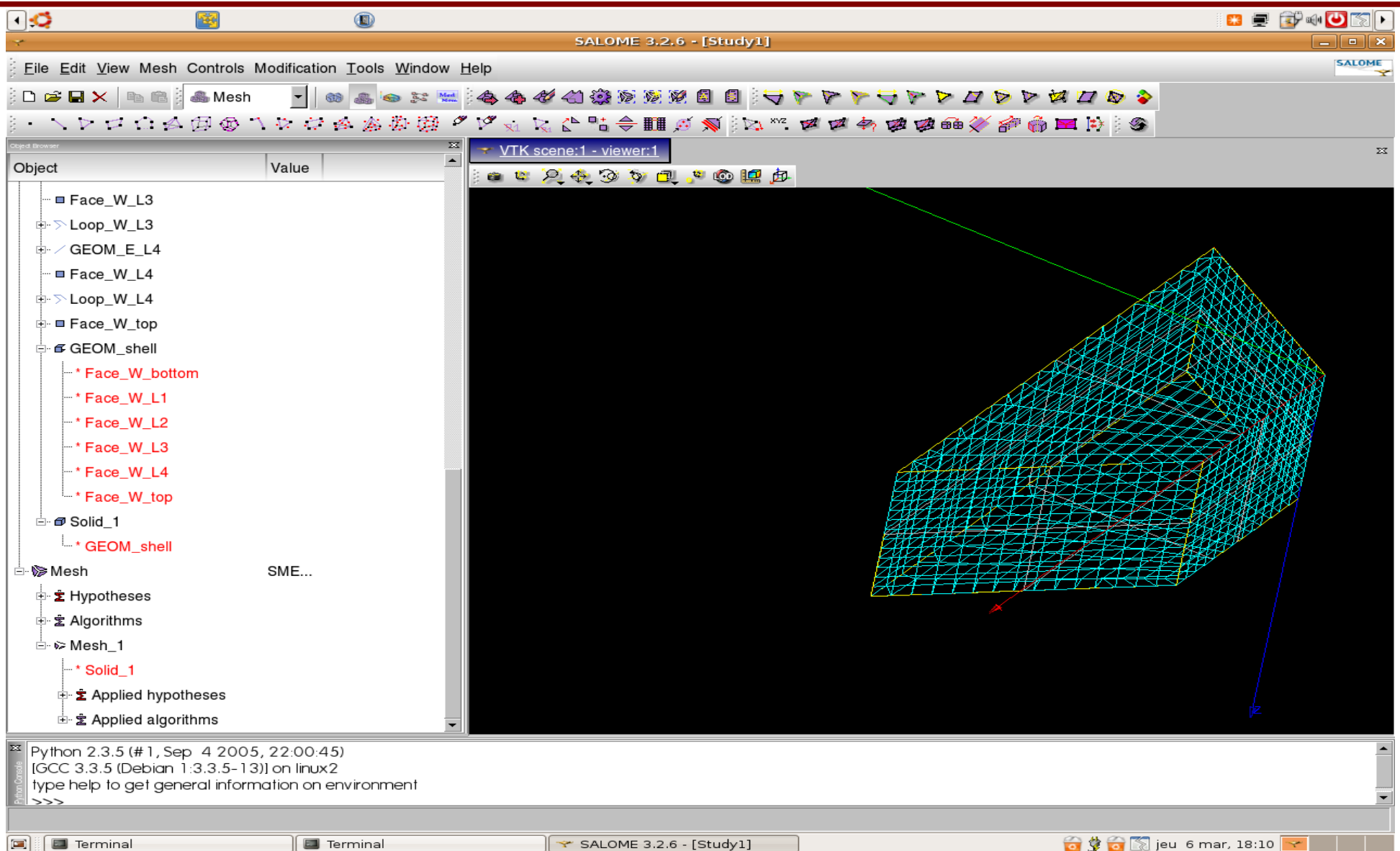
A consistent populated model...



Input in a CAD system after a simple xsl data conversion



Check model consistency



We may have continued modelling CSG trees...

Conception : Henry Boccon-Gibod

Ontologie : X3D CAD Profile ontologic study
élément : owl:Class
rdf:ID : CSG_Solid_Class
rdfs:label : CSG Solid
rdfs:comment : A CSGSolid is...

index

CSG Solid

- Solid
- Substraction_Class
- Union_Class
- Intersection_Class
- Complement_Class
- Substraction_Class
- Union_Class

≤ 1 first diadic operand

operand

≤ 1 second diadic operand

Terminé

FoxyProxy: Désactivé(e)

Then, we had to build a proposal for the X3D CAD profile

- Simple issue :
 - As most of (but not all) standards based on XML, X3D is defined by an XML schema.
 - Our prototype is based on RDF, using a metamodel defined in OWL.
- Prior to propose our extension of X3D we needed to convert the metamodels, through an XSL transformation from semantic OWL to structural XSD.
- Some rules we state :
 - Define new Nodes (complextypes) from OWL classes,
 - Transform subclass trees into inverted composition trees,
 - Transform DataTypeProperties into attributes,
 - Transform ObjectProperties into Xlink cross references,

Need of implementation(s)

- EDF missionned Alexandre Frouard, a young, brilliant, developer, at Yumetech, in order to build a first implementation of BREP in X3D.
 - The proposal was discussed, as we did in EDF...
 - Some modification were suggested and tried... but at the end the result was quite similar to what we designed.
- The first implementation were demonstrated at the 2009 Web3D conference in Darmstadt.
- ...but to day, a second implementation is still waited !

An emerging idea

- Some time ago, I was working on some protocols of extension of ISO 10303 STEP standard.
 - STEP standards are based on metamodels defined in EXPRESS language, that now appear to be a kind of ontology language.
 - At least one of STEP standard (ISO 15926, about AEC) has moved from EXPRESS to an RDF/OWL expression.
- Would it be possible to get an RDF expression of the X3D standard ?
 - So I tried to build it using an inverse transformation of the whole edition of the X3D XML schema from XSD to OWL, using same rules as the previous one, inverted.

So an owl expression of X3D may be something like that

Conception : Henry Boccon-Gibod

Mozilla Firefox

file:///home/he...ometryNode.svg

index

rdfs:label : X3DGeometryNode

rdfs:comment : X3DGeometryNode

X3DGeometryNode : X3DNode {
 SFNode [in,out] metadata NULL [X3DMetadataObject]
}

This is the base node type for all geometry in X3D.

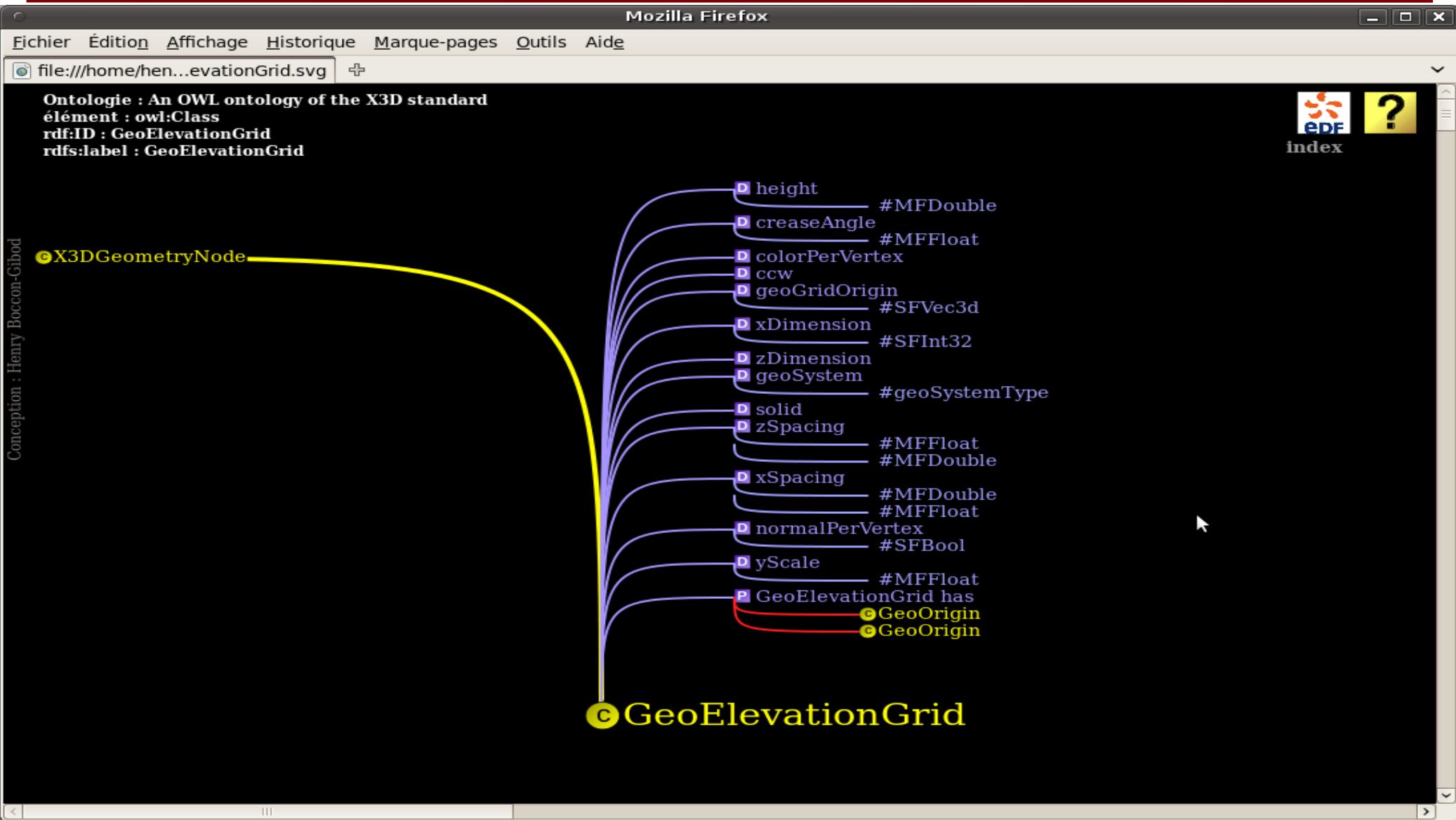
X3DNode

X3DGeometryNode

containerField <http://X3D.owl#xs:NMTOKEN>

- X3DComposedGeometryNode
- Arc2D
- ArcClose2D
- Box
- Circle2D
- Cone
- Cylinder
- Disk2D
- ElevationGrid
- Extrusion
- GeoElevationGrid
- IndexedLineSet
- LineSet
- PointSet
- Polyline2D
- Polypoint2D
- Rectangle2D
- Sphere
- Text
- TriangleSet2D
- X3DNurbsControlCurveNode
- X3DParametricGeometryNode

All concepts semantically linked



But some (in fact a lot of) things appear inconsistent..

Ontologie : An OWL ontology of the X3D standard
élément : owl:DatatypeProperty
rdf:ID : weight
rdfs:label : weight
rdfs:comment : type = "MFDoubl"
rdfs:comment : type = "MFFloat"
rdfs:comment : type = "SFFloat"

#MFFloat

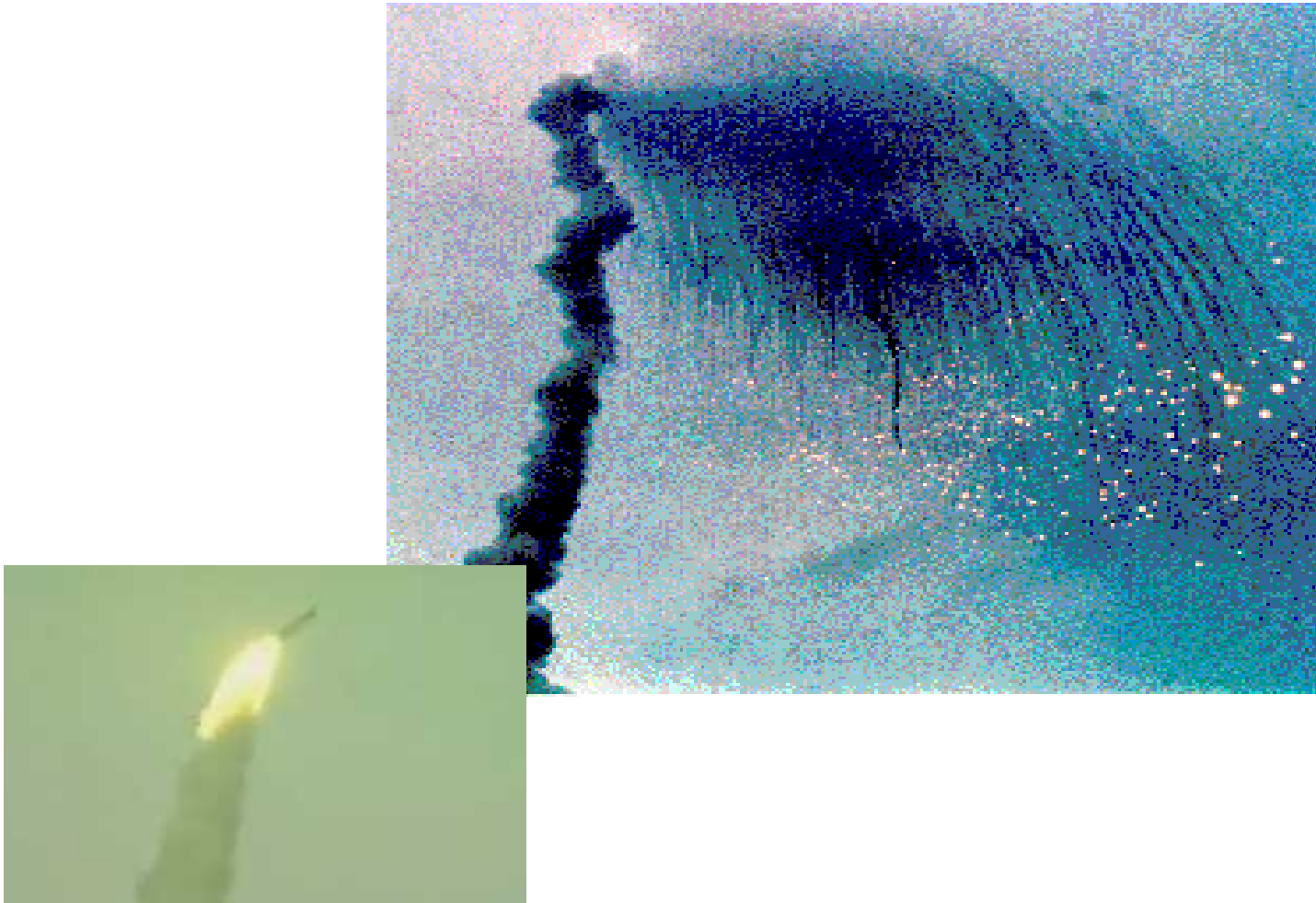
MFFloatle

weight

- X3DNurbsSurfaceGeometryNode
- HAnimDisplacer
- NurbsCurve
- NurbsCurve2D
- NurbsOrientationInterpolator
- NurbsPositionInterpolator
- NurbsSurfaceInterpolator
- NurbsTextureCoordinate
- X3DNurbsSurfaceGeometryNode
- HAnimDisplacer
- NurbsCurve
- NurbsCurve2D
- NurbsOrientationInterpolator
- NurbsPositionInterpolator
- NurbsSurfaceInterpolator
- NurbsTextureCoordinate
- X3DNurbsSurfaceGeometryNode
- HAnimDisplacer
- NurbsCurve
- NurbsCurve2D
- NurbsOrientationInterpolator
- NurbsPositionInterpolator

That remind me an experimental result
of some kind of data type discrepancies...

That was the first flight of Ariane 5,



Questions

- Issues :
 - What are compared advantages/disadvantages of semantic (OWL) versus structural (XSD) expression ?
 - easier extensibility and consistency of OWL expression ?
 - easy semantic extension of any kind ?
 - possible benefits of rule languages attached to owl ?
 - Model consistency checking ?
 - Possible lack of efficiency issues due to OWL APIs ?
 - (Jena, OWLAPI etc.)
 - To change expression kind, would it be a revolution ?

Thank you