Institut Graphische Datenverarbeitung

VICOM Tech VISUAL COMMUNICATION TECHNOLOGIES

Ontology Modelling of Industry Standards for Large Model Visualization and Design Review using Protégé

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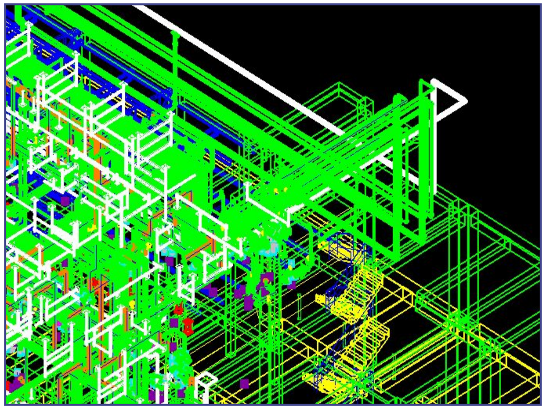
Roadmap

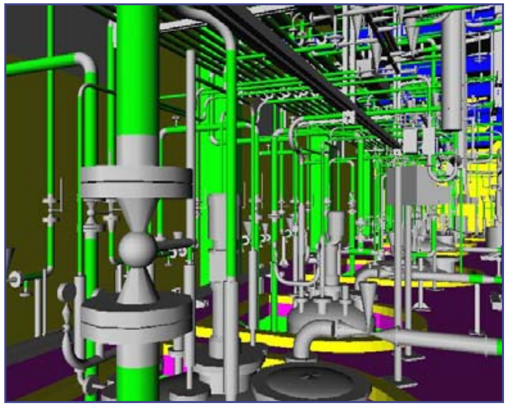
- Motivation
- Background
- An architecture for the semantic compression of CAD models
- Catalogue reconstruction
- STEP based Ontologies
- Semantic Simplification of Large CAD models
- Case Studies
- Conclusions

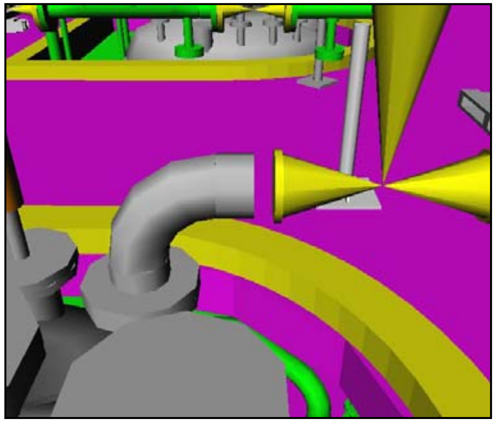
Motivation

Why view a plant / Steel Detail Structure model in a Virtual Walkthrough Environment (Large Model Visualization)

- In Design Reviews during Design
    - Design errors appear obvious
    - Avoid costly corrections during the construction phase
- Complex CAD models are hard to interpret
    - Natural navigation and perception in VR environment







Background

- Problem: A typical CAD-Model of a large plant has about 2-20 Million triangles
- Standard export from CAD Software and VRML Viewers reach their limit at models with 1 Million triangles
- Complete models of planes/ships produce between 80 Million and 500 Million triangles
- Some applications are able to view models close to 80 Million triangles using expensive hardware, extensive software and preprocessing times of hours or days.
- Steel Detailing models are about 1.5 - 10 Million of triangles.

Power plant with 13 Million triangles

Background (II)

FACTS

- In order to visualize large CAD models, classical CG techniques can be used:
  - Culling techniques (Drop, Occlusion, Visibility), Levels of Detail (LOD) and hardware acceleration.
- Even using traditional CG techniques, some models cannot be handled by a normal PC.
- The semantic information embedded in a CAD model is hardly used.
- Different users have different profiles and knowledge (manager, engineer...)
- Different models have different structures (Plant, Aircraft, Steel Detailing, Boats)
- The elements of a CAD-drawing have meanings (valve, pipe, wall, bolt, profile, joint...)

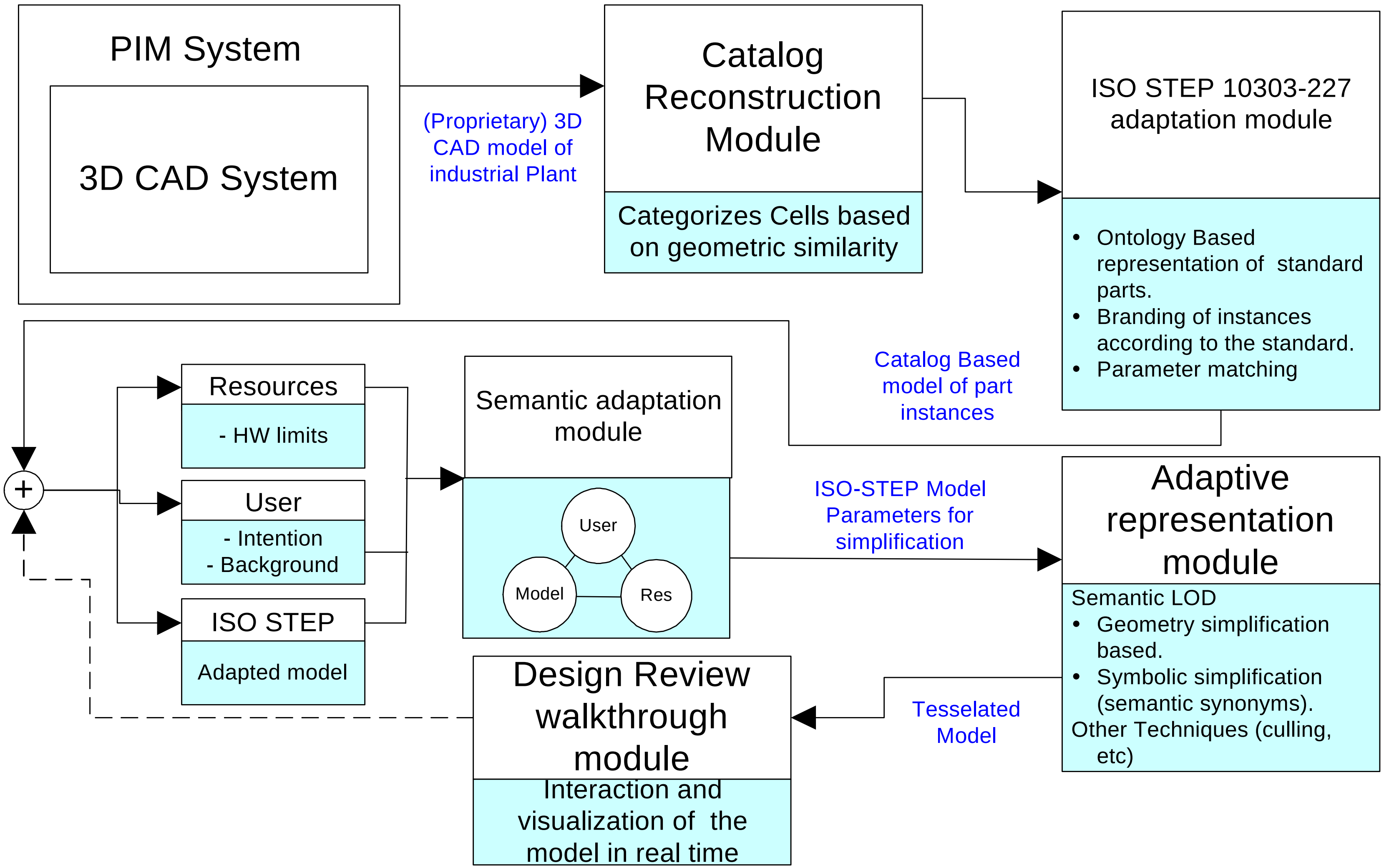
Background (III)

Problem Statement

Until now all the approaches followed are targeting simplification techniques based in resources handling and database management.

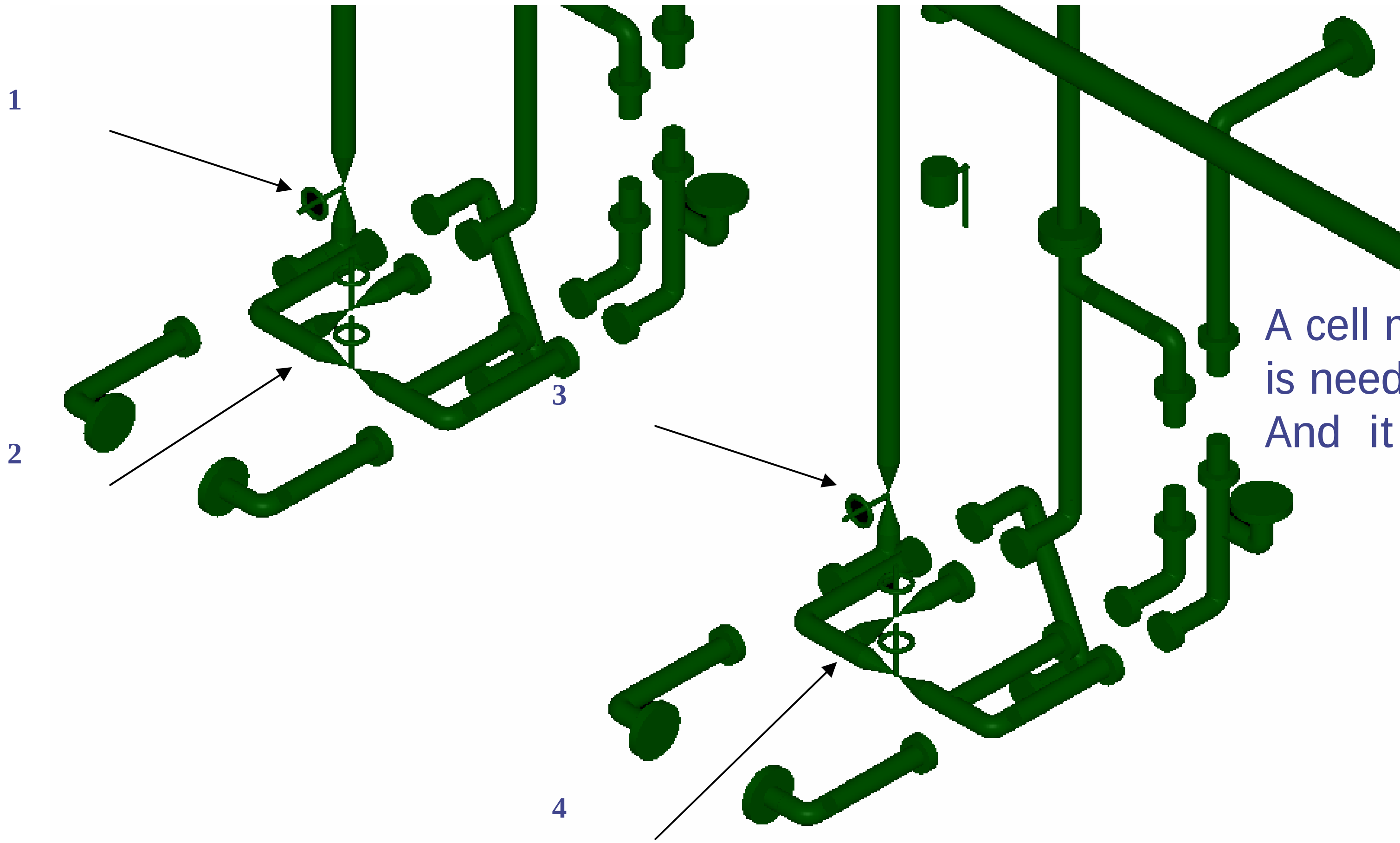
How do you do to enhance a visualization experience taking into account semantic factors?

Architecture



Catalog Reconstruction

This module traverses the 3D CAD model identifying groups of geometric primitives (we call these groups/families cells)



A cell matching algorithm is needed!!
And it must be fast !!

Catalog Reconstruction (II) – Cell matching

Given two cells **Ci** and **Cj**, each composed by an unordered set of geometric primitives, **Cj** matches or is an instance of **Ci** if a rigid transformation (rotation/ translation) matrix T exists that transforms **Cj** into **Ci** The cell-matching algorithm must:

(i) Decide if **Cj** matches **Ci** within a given tolerance.

(ii) Obtain the transformation matrix **T**.

Traditional algorithms to solve this problem are either Point cloud oriented or topology based.

We have developed a fast algorithm to solve this problem

STEP Based Ontologies

A 3D model of an Industrial Plant or a Steel Detailing model of a structure typically has representations of pre-defined engineering parts.

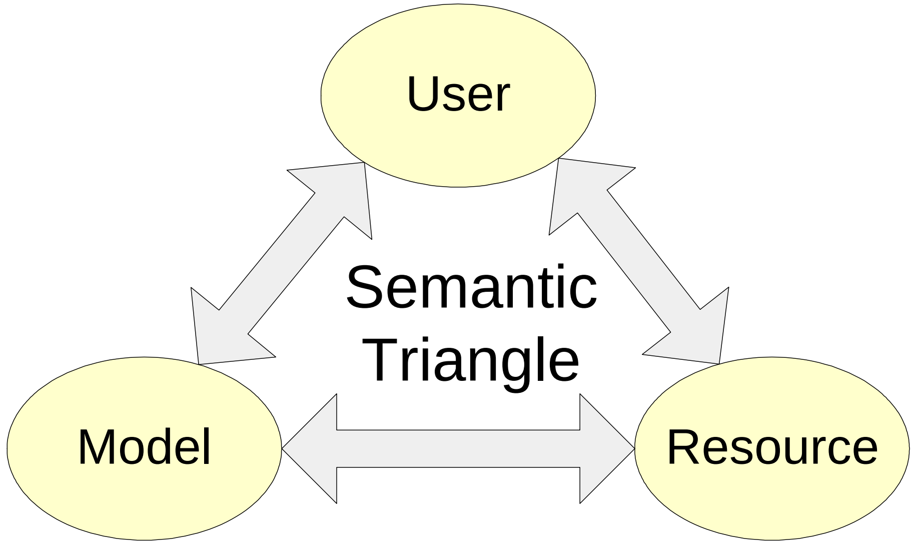
These elements are described by an ISO standard, STEP-10303-227 in the domain of Plant Design, and CIS/2 in the domain of Steel Detailing

STEP Based Ontologies

We have modelled a full Ontology related to the ISO-STEP standards in both case studies (Industrial Plant and Steel Detailing) because our ultimate objective is to have a system where the concepts and relationships of the domain could be modeled and queried using semantic criteria

STEP Based Ontologies

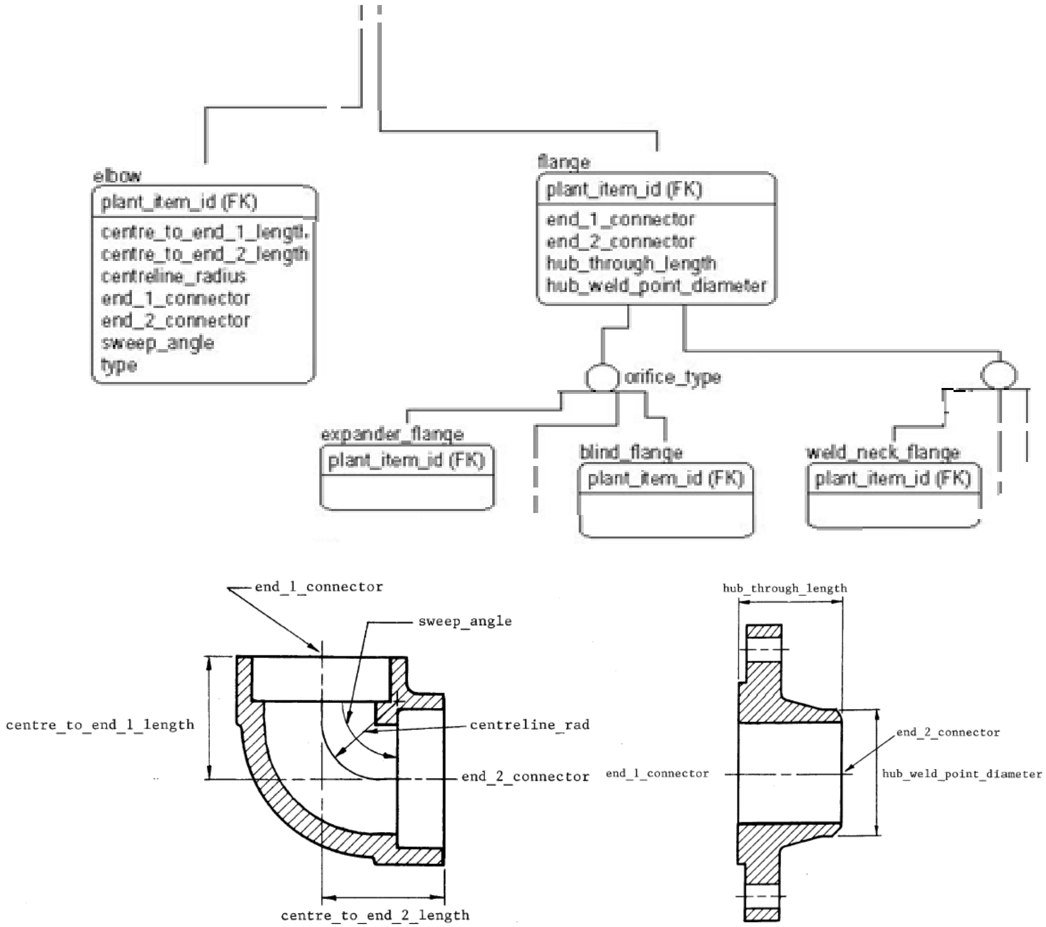
User needs, background, profile



Every model has different information embedded, the model must be expressed if possible in an standardized way.

Computer resources must be monitorized, e.g Frames per second, Number of triangles capable to draw per second, available RAM, Processor availability.

STEP Based Ontologies (II)



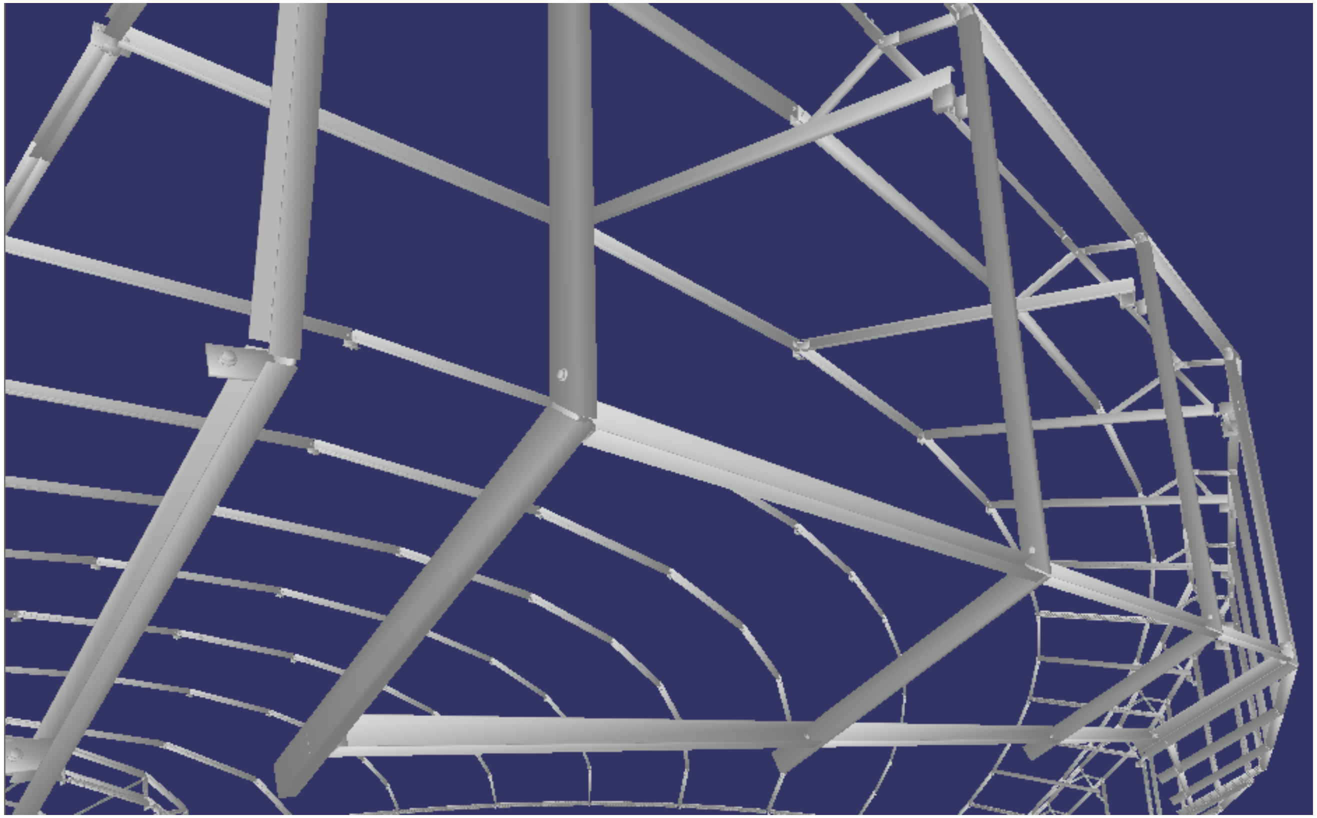
STEP (10303 Standard) is an international ISO normative.

The objective of STEP is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product independent from any particular system.

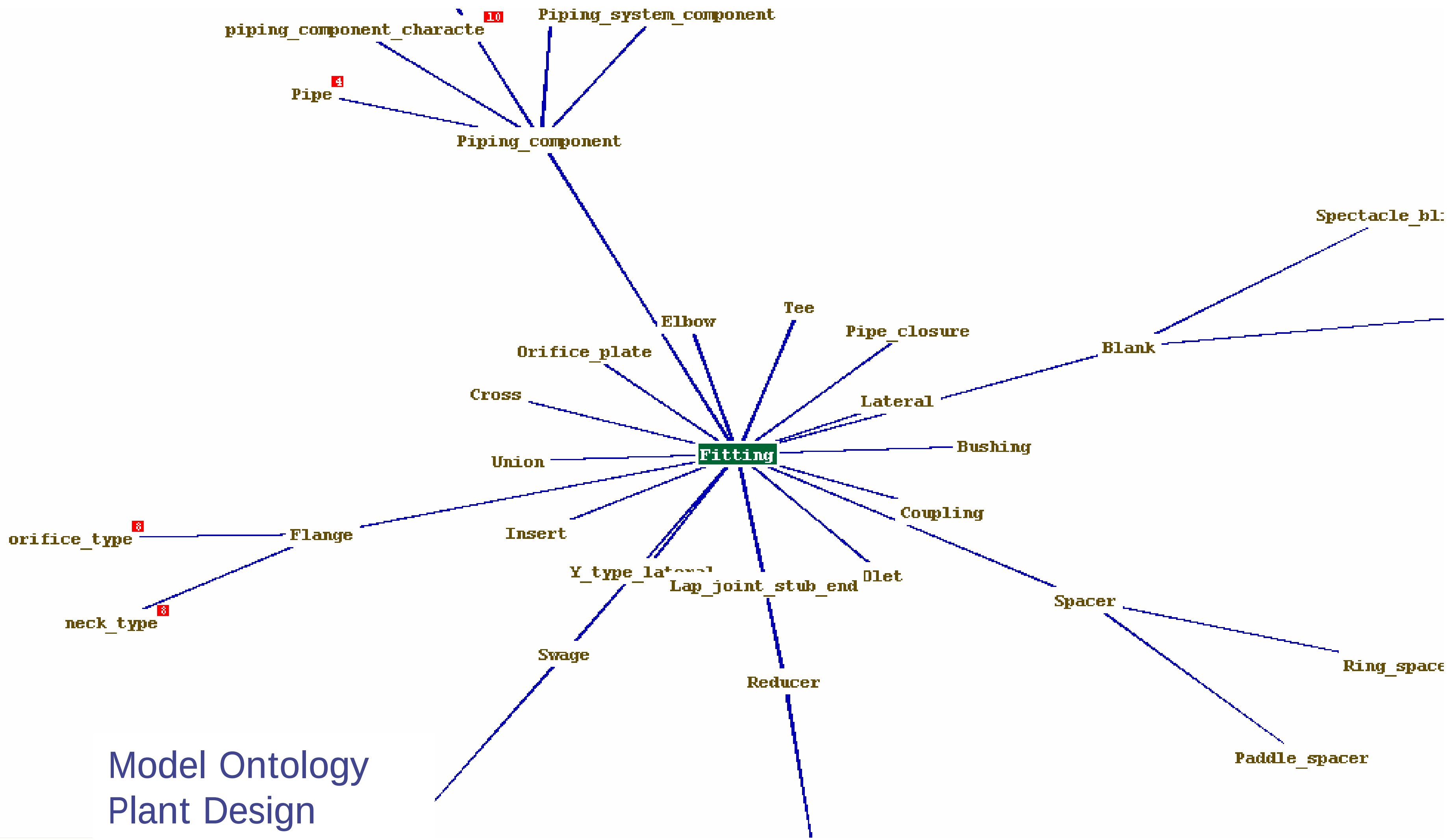
The Application protocol 227 describes the specifics for plant spatial configuration.

STEP Based Ontologies (III)

CIS/2 is based on deliverables of the Eureka EU130 CIMSteel Project and is an extension to the general STEP model for the specific case of the Steel Detailing industry.

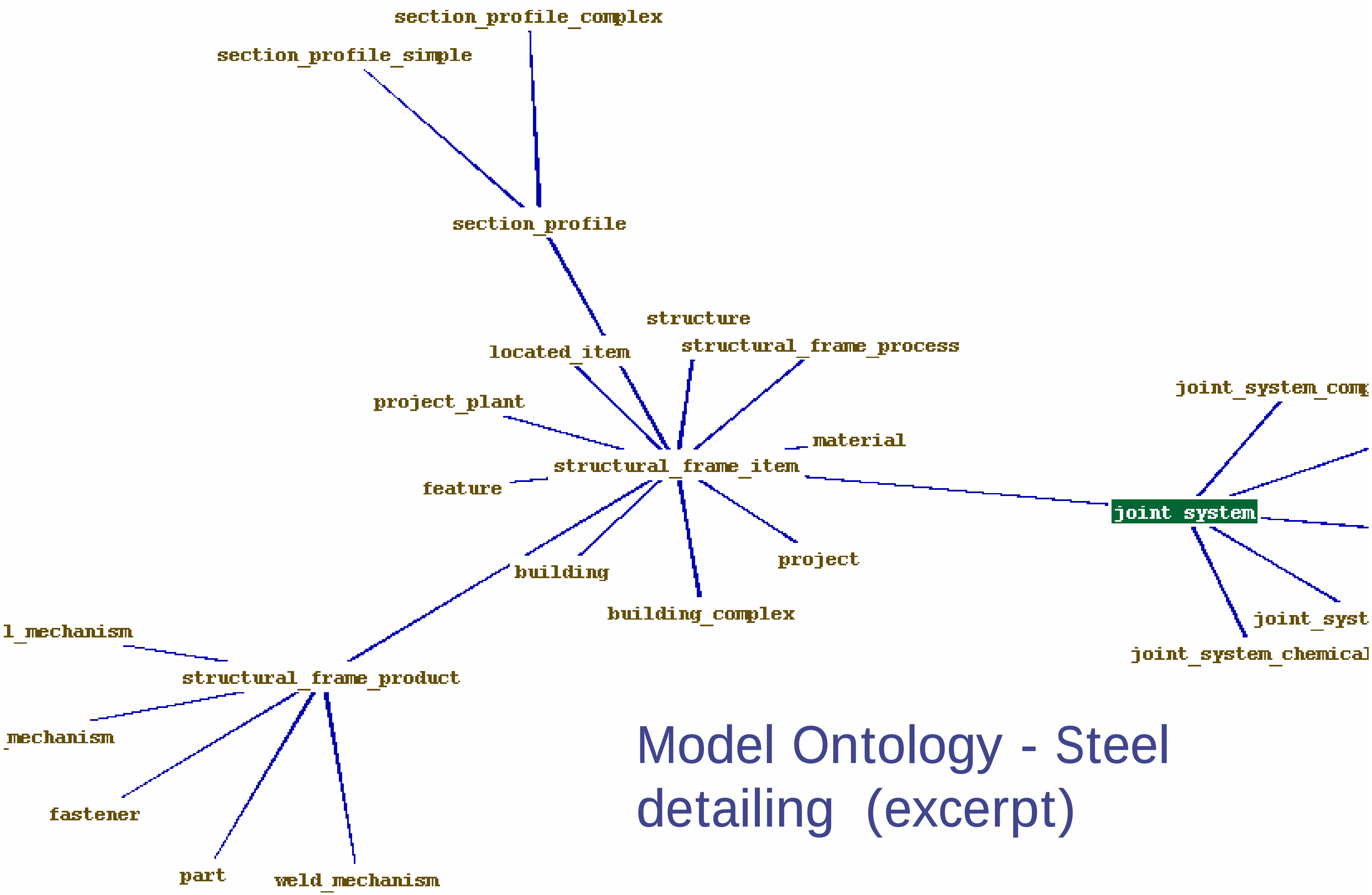


STEP Based Ontologies (IV)



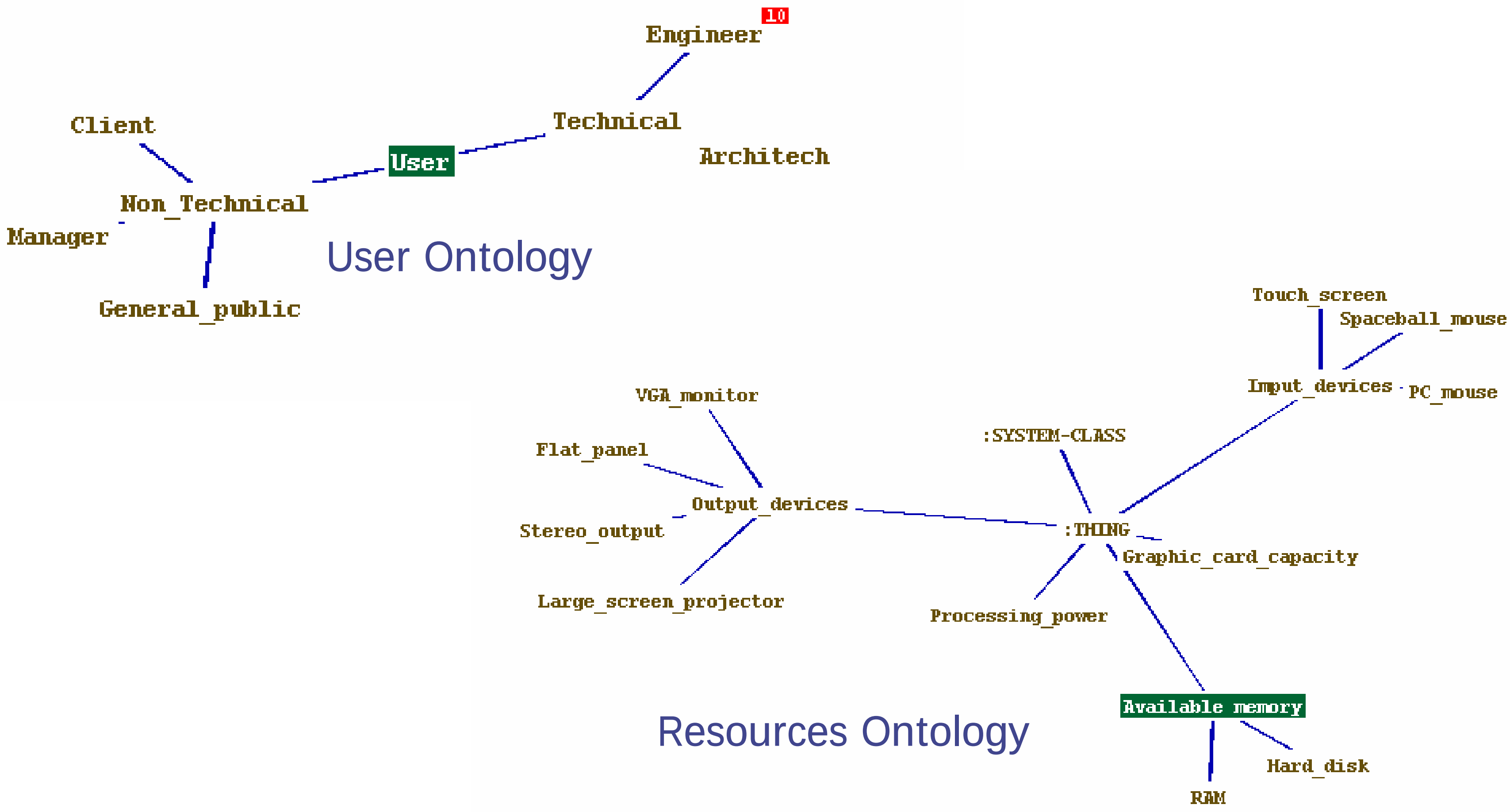
Model Ontology
Plant Design
(excerpt)

STEP Based Ontologies (V)

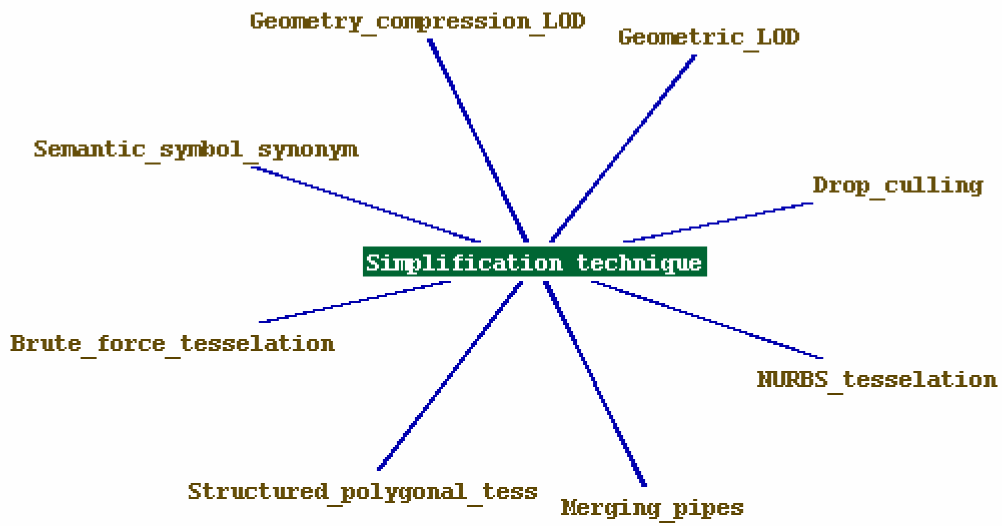


Model Ontology - Steel detailing (excerpt)

STEP Based Ontologies (VI)

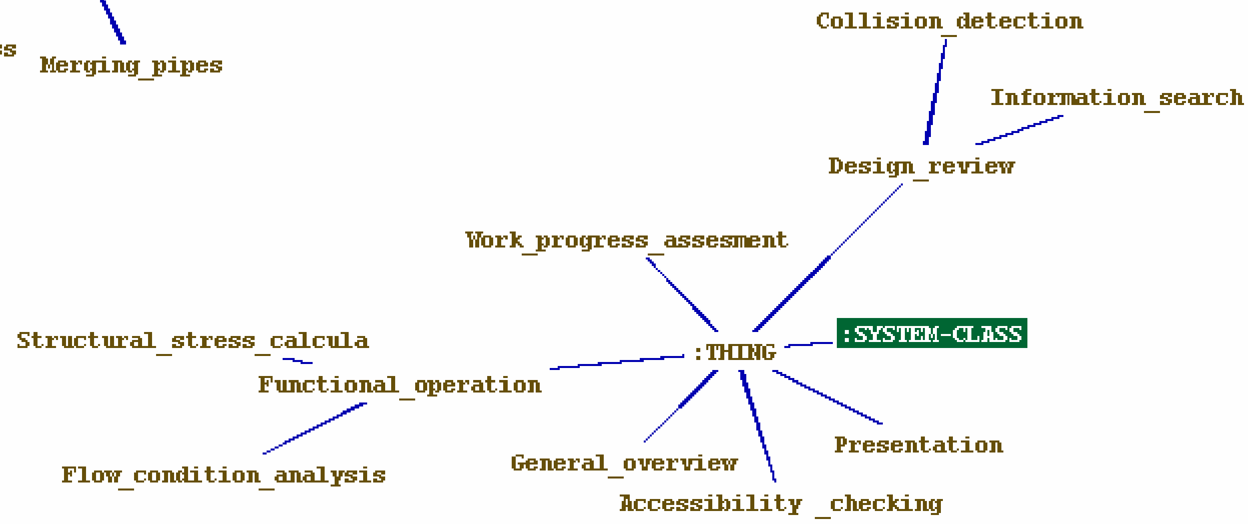


STEP Based Ontologies (VII)



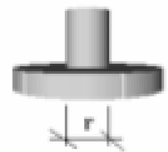
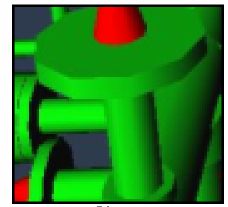
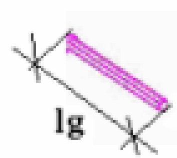
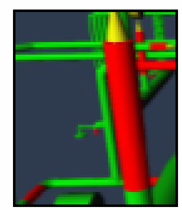
Techniques Ontology

Task Ontology



Semantic Simplification

The model Ontology is filled with the real parameters of the CAD model, and then a semantic association followed by a semantic adaptation allows the visualization enhancement by producing an output that has embedded just the needed information for each user, resources, task and profile (modelled as Ontologies as well)

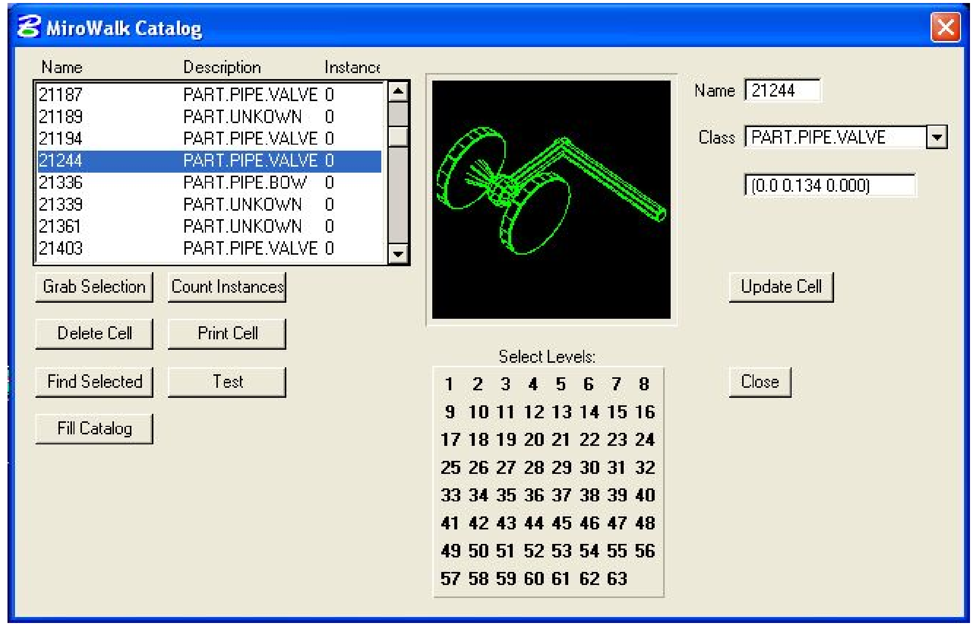
3D CAD (Geometric LOD)	Selected Semantic representation (parametric)	ISO-STEP Matched parameters
ISO-STEP 10303-AP227 FLANGE (COD. 4.2.84)		
	 **r** = radius **s** = side **XYZ** = Coord. System **P** = position (px,py,pz)	**STEP 4.2.84.3** Hub through length = s **STEP 4.2.84.4** hub weld point diameter = 2*r **STEP piping** connectors : give XYZ, P.
ISO-STEP 10303-AP227 STRAIGHT_PIPE (COD. 4.2.232)		
	 **c** = complexity **r** = radius of joint **XYZ** = Coord. System **P** = position (px,py,pz) **lg** = length	**STEP4.2.52.3** end to end length = lg **STEP piping** connectors : give r, XYZ, P.

Semantic Simplification (II)

The simplification of elements has two stages

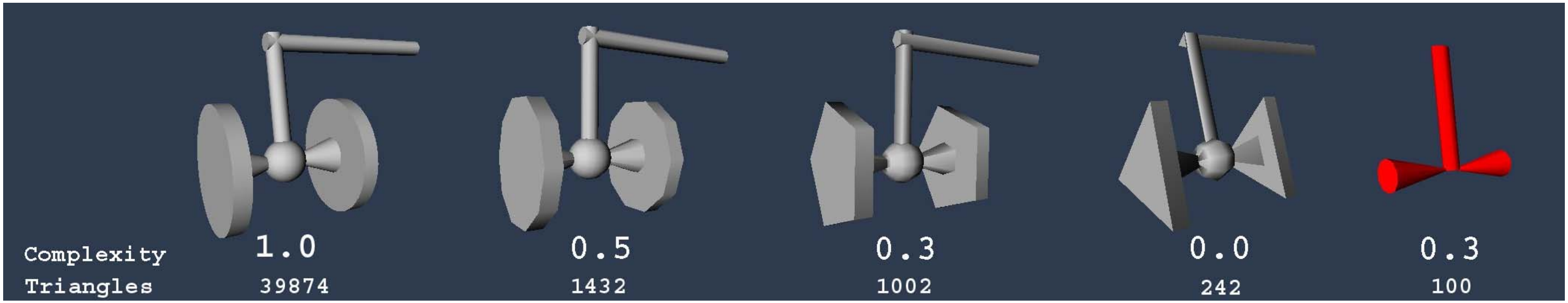
1) Name each group of cells after an ISO – STEP compliant concept. We call this process “Branding”. The user visualizes one representative part of the cell group and matches it with a concept of the Ontology in a graphical concept tree.

2) Once the cell group is associated with a concept in the Ontology domain, the user matches semi-automatically the cell parameters (geometric features) with those parameters specified in the ISO-STEP standard. We call this process “Matching”.



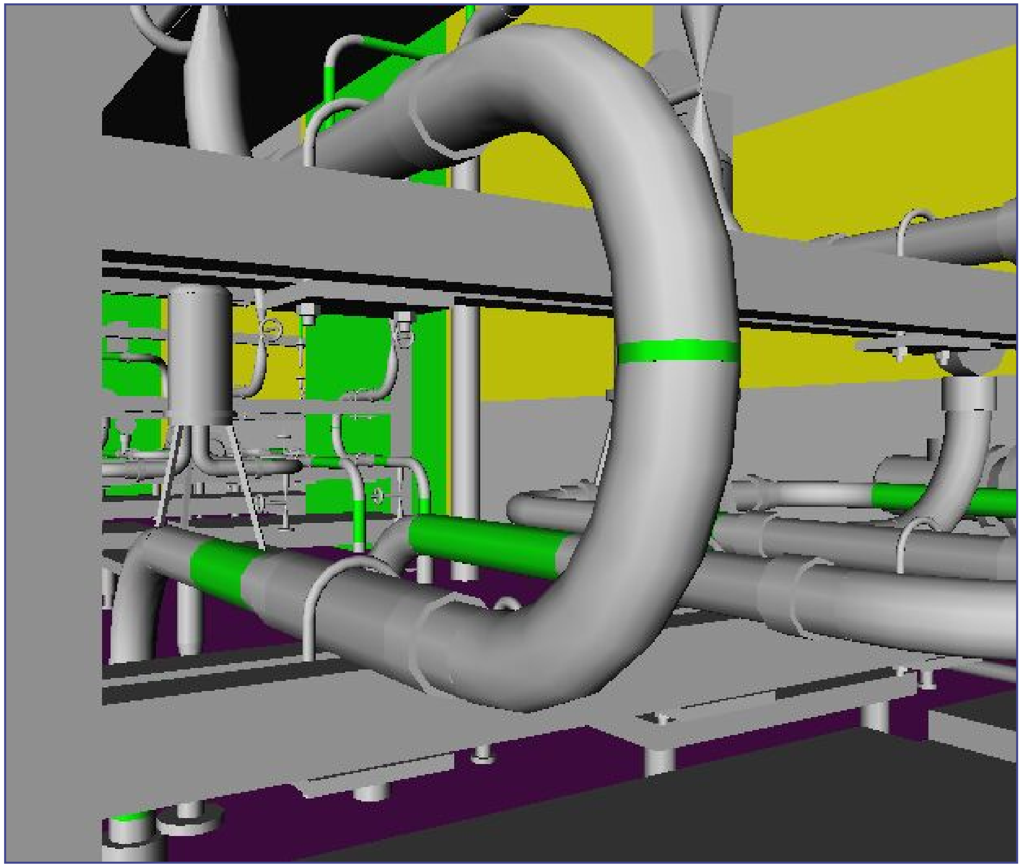
Semantic Simplification (III)

- Replace a part with a less complex to render 3D symbol of the part
- If the user knows the symbol -> associated semantic is kept
- 3D Symbols is a Semantic Synonym
- Simple idea - but a big triangle saving:
  - 900 * 1000 Triangles = 900.000 Triangles saved !
- Only possible IF the user knows the symbol
- Thus system hast to be aware of the visualization context



Semantic Simplification (IV)

Example : Chemical Plant Model

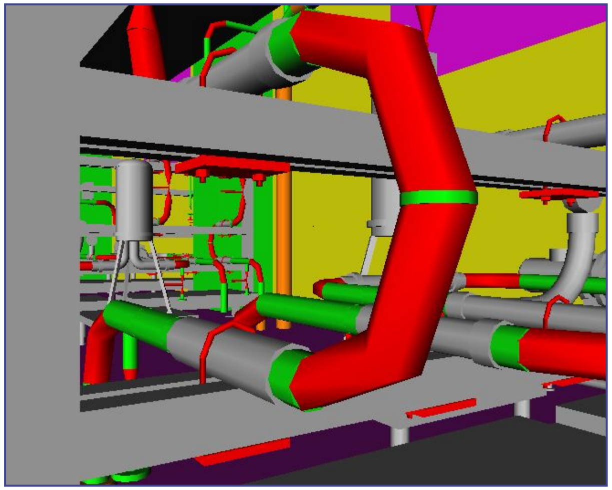


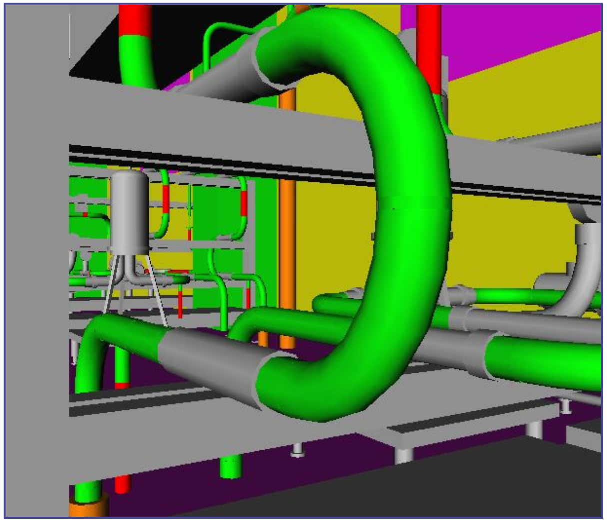
Question: How to optimize this scene?

Answer: **Depends on who is viewing it**!

Semantic Simplification (V)

- 1. Viewer is an Engineer:
  - Has technical/conceptual perception
  - Model does not need to be pretty but functional
  - Show details but in reduced visual quality
- 2. Viewer is a Manager:
  - Has general/esthetical perception
  - Hide Details (e.g. Clamps)
  - But render with high visual quality





Quality is relative to the User's Intention!

Case Study Industrial Plant :

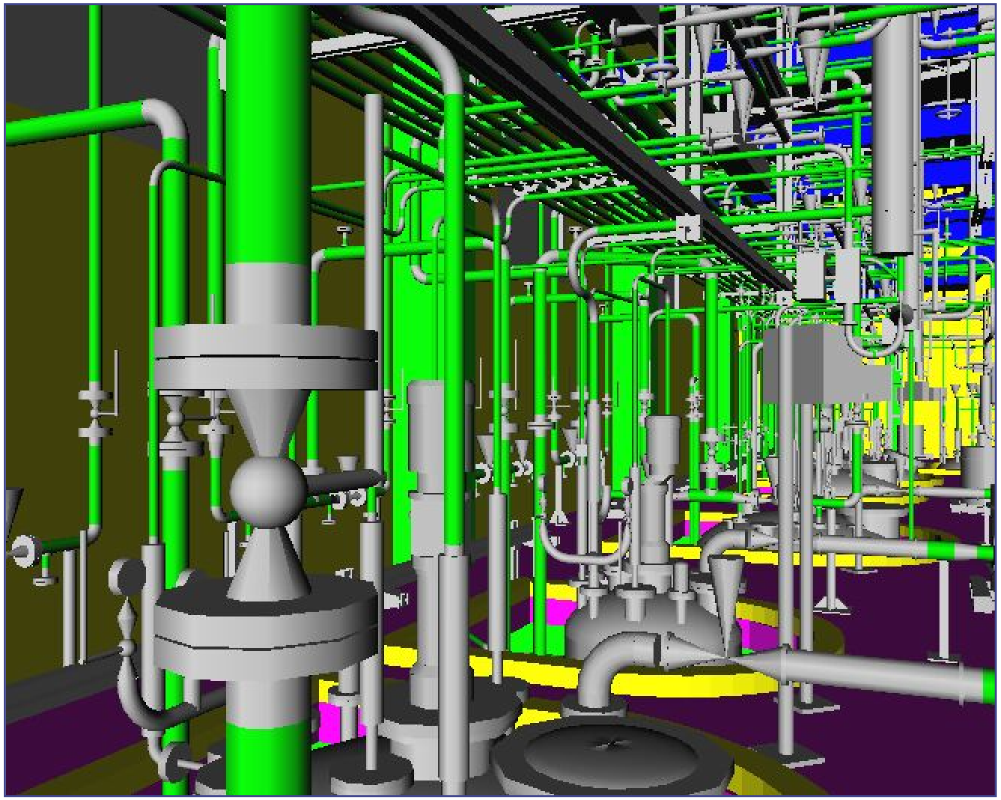
Plant Design Component	Number of Instances	% of total instances
Valves	867	7 %
Elbows	2064	16 %
Flanges	3663	28 %
Pipe Section	3509	27%
T-adaptors	425	3%
Clamps	191	1%
Unknown	2428	18%
Total Cells	13147	100%

Categorization in cell families

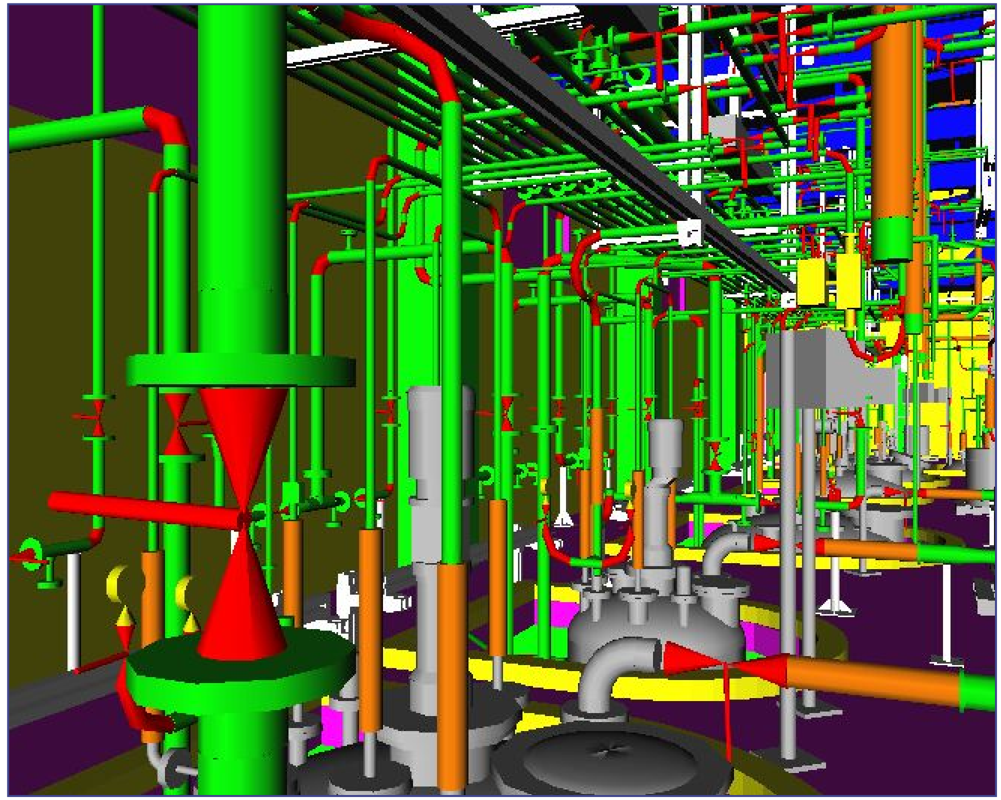
The tessellated model using only geometric LOD plus some culling / fetching techniques gave an average number of triangles of 3450 Ktris, with a complexity of 0.3

Applying the semantic compression model, we reduced the model in additional 1659 Ktris, for a net reduction of 51% in the total number of triangles between the semantically compressed model with respect to the geometric LOD simplified model.

Case Study (II) Industrial Plant :



Not semantically compressed view



Semantically compressed view

Case Study (III) Steel Detailing Structure :

CIS/2 compliant Steel Detailing Element	Number of instances	% of total instances
Profile (CIS/2 Structural Frame Item - Profile)	3000	15%
Joint Tube-Sphere (CIS/2 Joint)	3000	15%
Screw (CIS/2 Fastener Simple Bolt)	6000	30%
Tube (CIS/2 Structural Frame Item - Profile)	6010	30%
Sphere (CIS/2 Node)	1500	7%
Unclassified	743	4%
Total Cells	19510	100%

Categorization of elements

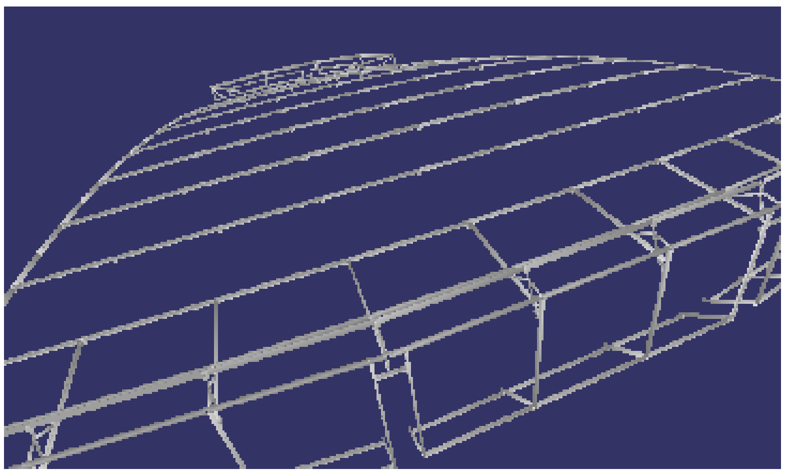
Case Study (IV) Steel Detailing Structure :

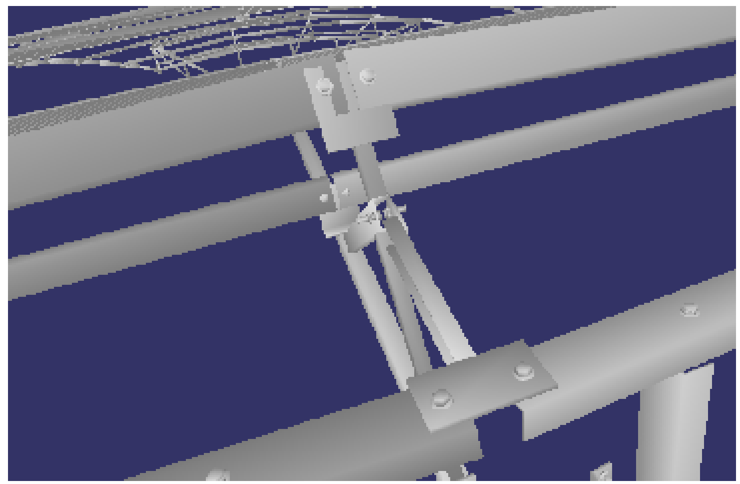
Steel Detailing Element	Without Semantic Simp.		With Semantic Simp		% Reduction
	Tris per cell	Tris per family	Tris per cell	Tris per family	
Profile	28	84000	18	54000	36%
Joint	20	60000	12	36000	40%
Screw	156	936000	46	276000	71%
Tube	68	408680	42	252420	38%
Sphere	2018	3027000	242	363000	88%
	Total	**4515680**	**Total**	**981420**	**78%**

Number of triangles reduction using semantic criteria.

Case Study (V) Steel Detailing Structure :

In this case we were also able to exploit the semantic information returning camera positions to the CAD program, showing that this approach can be used also to aid the designer in the design process.





Conclusions

- The use of the semantics implicit in the geometric models (especially, the fact that it is composed by standard engineering parts), and in the user intention and background, have given a sensible improvement in the application of standard computer graphics techniques.

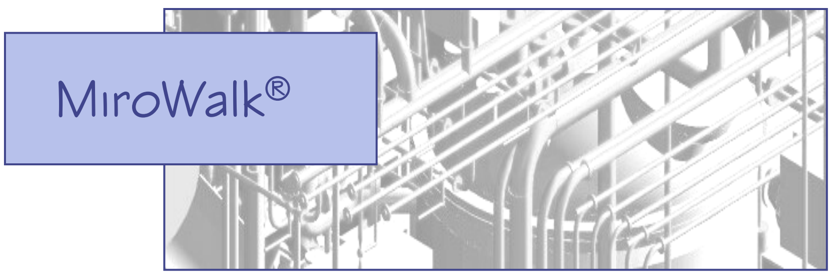
- The use of Ontologies related to international normative (ISO-STEP 13013-AP227 and CIS/2) add an extra standardization approach to our work

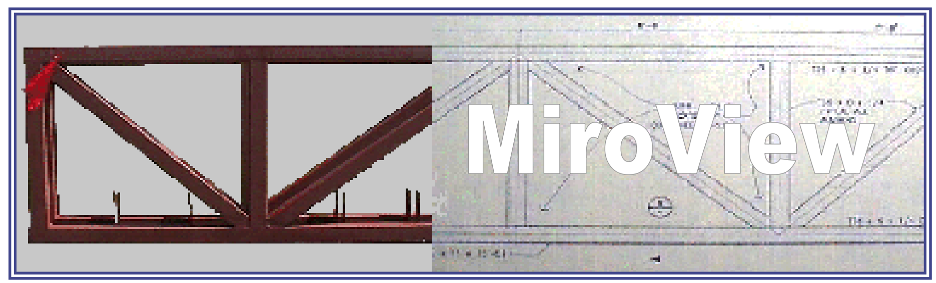
Conclusions (II)

- The degree of knowledge of the user in our approach is related directly to the knowledge of the domain, however no special familiarity with Ontology modelling and queering is needed as this module is not visible to the end user.

Thank you for your attention

Any questions?





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