Semantic X3D

Thoughts and Ideas

Discussion drafts by
X3D Semantic Web Working Group

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What is a semantic description of a scene

A potential semantical description of a 3D scene is an expression that should support and “answer” semantic queries.

Reasoning and Inference inquiries include Structural, Conceptual, Functional and additional aspects of 3D models.

Semantic queries are implemented on named graphs, linked-data or triples.

Correlation of multiple structured vocabularies is essential for enabling meaningful semantic descriptions of models used in diverse subject domains.

Structural semantic info in 3D models, scene graphs

● Geometry ● Motion ● Color	● Textures ● Viewpoints ● Lighting	● etc.

Examples: number of index values, curvature, velocity, color, Texture pattern, brightness…..

Example query: TODO

Examples of implementations (structural semantics)

More or less X3D covers all these in XML format.

In 3D Modeling Ontology there is an OWL DL ontology created from X3D v3.3, presenting the structural properties of the scene

- http://3dontology.org

In the past we presented MPEG7 descriptors and some extensions that may provide semantic of structural representation of scenes

- http://mpeg7.org
- http://medialab.teicrete.gr:8080/X3DtoMPEG7Tool/mainPage.html

Conceptual semantic info

- Goal:
  - Creation
  - Description
  - Exploration

of 3D content by non-IT-specialists, who use domain-specific concepts

- Spatial
- Domain specific
- ……..

Example terms: big, small, up, down, left, right,

Example query: TODO

Examples of implementations (conceptual semantics)

- Space representation
  - Spatial Indexing of Complex Virtual Reality Scenes in the Web (DOI: 10.1142/S0219467817005235) "Object Identification Based on the Automated Extraction of Spatial Semantics from Web3D Scenes" http://aetic.theiaer.org/archive/v2n4/p1.html
  - http://www.medialab.teicrete.gr/minipages/3DRtree/index.html
- Point cloud semantic segmentation
- VR/AR museums (http://semantic3d.org/publications)
  - Representation of artifacts, exhibitions using museum-specific concepts, e.g., coins, armors, sculptures
- Appliances, engineering
  - Representation of household appliances and their elements (e.g., induction hob, cookers) to build marketing contents
- Education and training
  - Representation of junctions, streets, buildings, traffic lights to create 3D scenes for training drivers

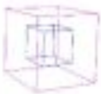
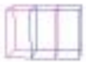
	Disjoint	(RectA.xMax <= RectB.xMin || RectA.xMin >= RectB.xMax) || (RectA.yMax <= RectB.yMin || RectA.yMin >= RectB.yMax) || (RectA.zMax <= RectB.zMin || RectA.zMin >= RectB.zMax)
	Touch	
	*Equal*	(RectA.xMin == RectB.xMin && RectA.xMax == RectB.xMax) && (RectA.yMin == RectB.yMin && RectA.yMax == RectB.yMax) && (RectA.zMin == RectB.zMin && RectA.zMax == RectB.zMax)
	*Within*	(RectA.xMin >= RectB.xMin && RectA.xMax <= RectB.xMax) && (RectA.yMin >= RectB.yMin && RectA.yMax <= RectB.yMax) && (RectA.zMin >= RectB.zMin && RectA.zMax <= RectB.zMax)
		Complementary relation: *CoveredBy*
		Opposite MBB relations: *Contains, Covers*
	*Contains*	(RectA.xMin <= RectB.xMin && RectA.xMax >= RectB.xMax) && (RectA.yMin <= RectB.yMin && RectA.yMax >= RectB.yMax) && (RectA.zMin <= RectB.zMin && RectA.zMax >= RectB.zMax)
		Complementary relation: *Covers*
		Opposite MBB relations: *Within, CoveredBy*
	*Overlap*	(SearchRect.xMin < Rect.xMax && SearchRect.xMax > Rect.xMin) && (SearchRect.yMin < Rect.yMax && SearchRect.yMax > Rect.yMin) && (SearchRect.zMin < Rect.zMax && SearchRect.zMax > Rect.zMin)

Table 1. *Topological criteria for 3D R-tree structure*

Reference to paper: http://aetic.theiaer.org/archive/v2n4/p1.html

Ontology available at:
TODO

Note that each of these relations can be determined using Shape boundingBox dimensions within a scene.

- All geometry contained in X3D Shape and grouping nodes support X3DBoundedObject interface
- Properties *bboxCenter*, *bboxSize*
- Not required to be present but they are easily computed and inserted by browsers, preprocessing tools

Are additional properties needed?

- Can be easily added, at first experimentally or later formally
- We can add new properties now, simply insert X3D Metadata nodes
- If we find that something is quite useful and commonly applied, then it is a candidate for addition to X3Dv4 specification.

	*Left*	RectA.xMax <= RectB.xMin
		Opposite MBB relation: *Right*
	Right	RectA.xMin >= RectB.xMax
		Opposite MBB relation: *Left*
	Above	RectA.yMin > RectB.yMax
		Opposite MBB relation: *Below*
	Below	RectA.yMax < RectB.yMin
		Opposite MBB relation: *Above*
	Over	(RectA.yMin == RectB.yMax ‖ RectA.yMax == RectB.yMin) && (!((RectA.xMax <= RectB.xMin) ‖ (RectA.xMin >= RectB.xMax)) && (!((RectA.zMax <= RectB.zMin) ‖ (RectA.zMin >= RectB.zMax)))
		Opposite MBB relation: *Below*
	*Front*	RectA.zMin >= RectB.zMax
		Opposite MBB relation: *Behind*
	*Behind*	RectA.zMax <= RectB.zMin
		Opposite MBB relation: *Front*

Table 2. *Directional criteria for 3D R-tree structure*

Note that all bounding boxes are computed for the contained geometry using in local coordinate space for each Shape.

However bounding boxes are compared in global coordinate space, which means translation/rotation/scale must be applied using the parent transformation hierarchy for each Shape, as well as appropriate UNIT definition for each scene.

Thus transformations must be applied in advance before these spatial relations can be computed for Shape pairs.

Also note that Shape geometry can be aggregated through use of Grouping nodes. However the fidelity of bounding boxes might become quite reduced as additional geometry is added together.

Reference to paper: http://aetic.theiaer.org/archive/v2n4/p1.html

Geometric properties

Example inquiry. Thanos, you said “sitting in my corner”
Can we define a property for “corner” based on geometric relationships? Good to think about.

We might suppose multiple candidate geometric properties:

- Primitive shapes: Rectangular, Conical, Cylindrical, Spherical, Ellipsoid, Point, Line, Mesh
- Side, TopSide BottomSide LeftSide RightSide FrontSide BackSide
- ParametricSurface, NURBS, BREP, other types?
- Characteristics: Irregular, Open, Closed (Watertight), Corner, Seam, Wall
- Angular relationships: Perpendicular, Acute, Obtuse

```
Thanos: corner rdfs:subClassOf

        str:includes(2) str:triangles;

If normal(A) CROSS-PRODUCT normal(B) >0 -> createCorner(C) and includes(C,A) and includes(C,B)
```

TODO: does there already exist a set of 3D property classes related to shape of models?
TODO: should we next compare existing 3D ontologies of interest?
TODO: build examples that help us determine the best, most reusable elements of an X3D ontology?

Geometric properties 2

As we discuss relationships and 3D functions for extraction of semantic information from geometric shapes, we can specify possible goals of our works:

- Extraction of semantic information from X3D models (re-visit MPEG7)
- Generating X3D models on the basis of semantic 3D models (conceptual)
- Likely an iterative process, OWL inference can generate more RDF properties
- Semantic annotation (description) of X3D (without representation)

Few things about MPEG-7 shape descriptors in link

https://docs.google.com/presentation/d/11VSFHriBnOXJzsHfYX0XDUMVqO5X9HePUvQB_1mxRRY/

Inclusion of Visual Descriptors in X3D

Visual Descriptors are available for color and shape. They seem quite analogous to structure provided by RDF properties.

It is an interesting question whether the X3D Specifications are “ready” for inclusion of visual descriptors. Visual-descriptor properties are primarily metadata about a scene, not directions for rendering. Indeed our current effort is to create such a conceptually coherent ontology for X3D.

Thus if we define how to include visual descriptor properties in a scene,

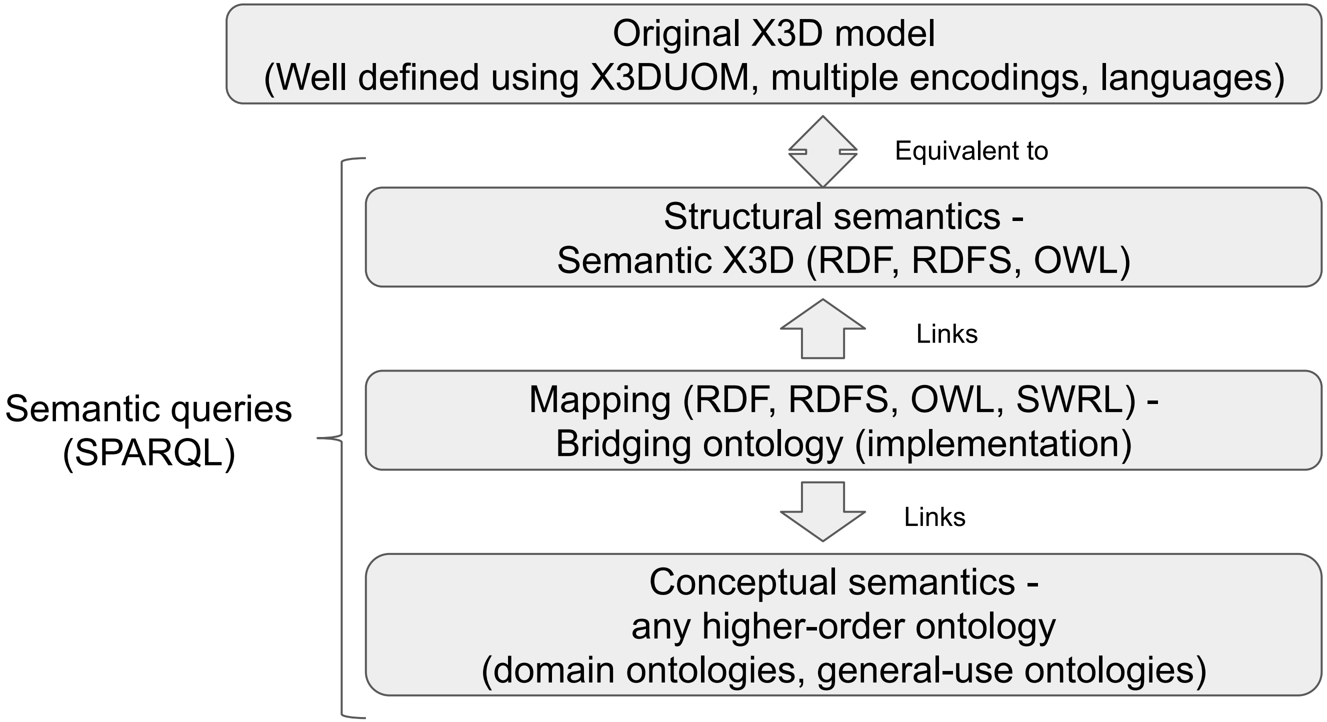
- Authors could include Metadata nodes with RDF properties,
- Tools could perform geometric inference and similarly add Metadata nodes

Attaching semantic information to X3D scenes

This working group needs to identify X3D Ontology mappings as

- embedded MetadataSet structures
- embedded (multi-namespace?) and external RDF files
- norms and best practices for including such descriptor files

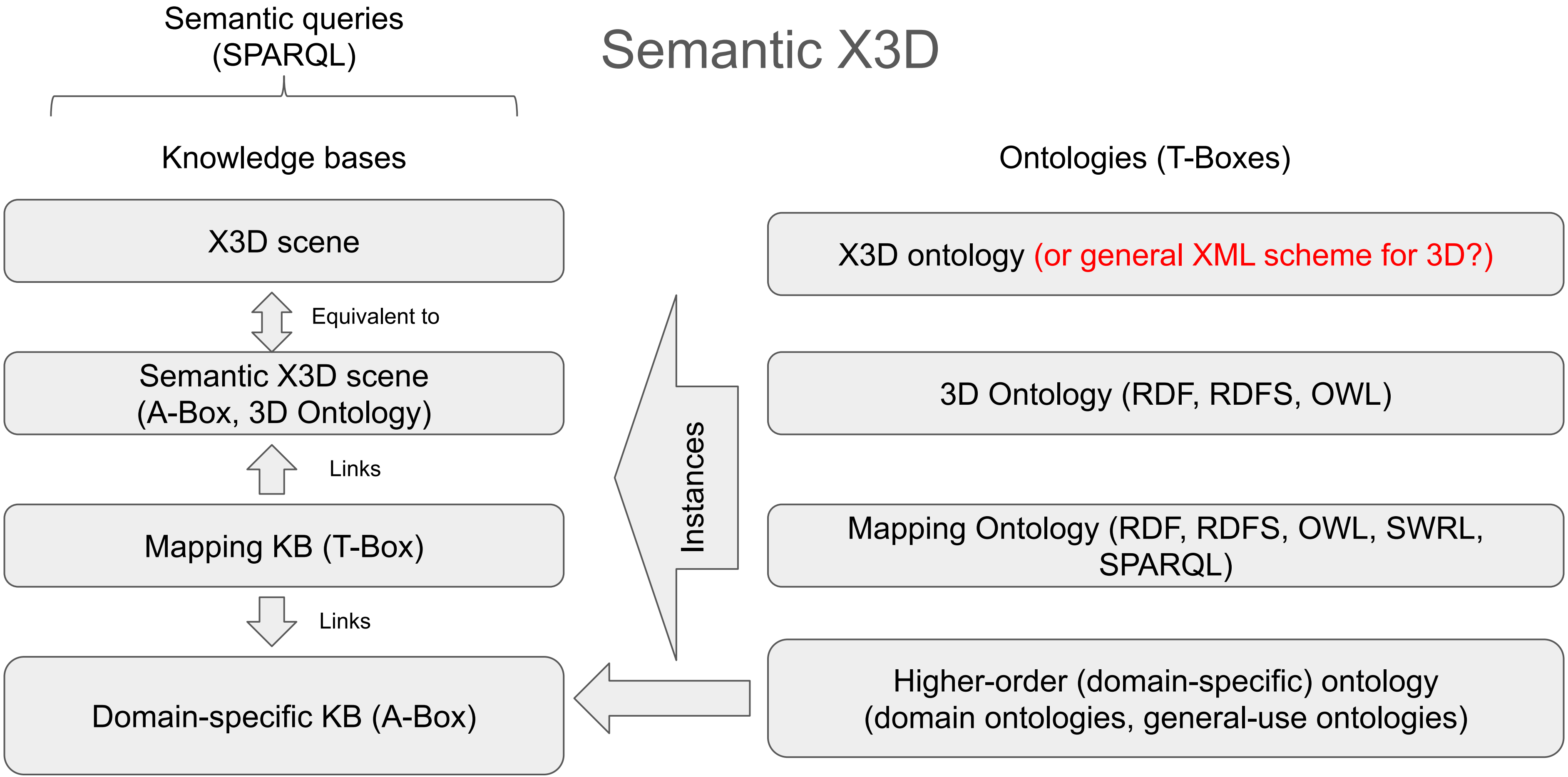
Composing semantic representations at different abstraction levels beyond X3D



Includes export of any 3D model with appropriate conversions and metadata

X3D-specific ontology

Be careful about OWLcomputational profiles:
https://www.w3.org/TR/owl2-profiles/
We should use as simple OWL profiles as possible to express structural and conceptual representations as well as mappings.
SWRL rules are undecidable in general.
A well-defined ontology needs to be tractable.


Semantic X3D
Semantic queries (SPARQL)
Knowledge bases
Ontologies (T-Boxes)
X3D scene
Equivalent to
Semantic X3D scene (A-Box, 3D Ontology)
Links
Mapping KB (T-Box)
Links
Domain-specific KB (A-Box)
Instances
X3D ontology (or general XML scheme for 3D?)
3D Ontology (RDF, RDFS, OWL)
Mapping Ontology (RDF, RDFS, OWL, SWRL, SPARQL)
Higher-order (domain-specific) ontology (domain ontologies, general-use ontologies)

Connecting semantic information with X3D scenes

Multiple approaches considered possible.

- Separate files, referenced by url from X3D scene
  - for example .rdf .owl .sparql files, etc.
- X3D scene referenced by url
  - For example, in RDF/OWL instances
  - Describing Semantics of 3D Web Content with RDFa, WEB 2013
- Embedded markup in single multi-namespace XML document
  - Concern that tool support might be difficult
- Re-expressing RDF/OWL syntax in X3D Metadata* nodes
  - At minimum need a MetadataSet convention for referring to semantic information

Example mapping of conceptual to structural representation (implementation of concepts)

In SWRL:

over(objectA, objectB) => parent(transformA, objectA) and parent(transformB, objectB) and translation(transformA, yA) and translation(transformB, yB) and yA>yB.

Example corner knowledge base

```
<http://www.semanticweb.org/jakub/ontologies/2019/1/untitled-ontology-14> rdf:type owl:Ontology ;
                                                owl:imports <http://purl.org/ontology/x3d/3d.ttl> .

:in rdf:type owl:ObjectProperty .

:ex-group rdf:type owl:NamedIndividual , <http://purl.org/ontology/x3d/Group> .

:ex-plane1 rdf:type owl:NamedIndividual , <http://purl.org/ontology/x3d/Plane> ; :in :ex-transform1 .

:ex-plane2 rdf:type owl:NamedIndividual , <http://purl.org/ontology/x3d/Plane> ; :in :ex-transform2 .

:ex-transform1 rdf:type owl:NamedIndividual , <http://purl.org/ontology/x3d/Transform> ; :in :ex-group ;

        <http://purl.org/ontology/x3d/rotation> "0.0"^^xsd:float .

:ex-transform2 rdf:type owl:NamedIndividual , <http://purl.org/ontology/x3d/Transform> ; :in :ex-group ;

        <http://purl.org/ontology/x3d/rotation> "2.0"^^xsd:float .
```

Example mapping of X3D shapes to domain “corner”

In semi-SWRL:

in(Transform1, Group), in(Transform2, Group), in(BB1, Transform1), in(BB2, Transform2), rotation(BB1, x), rotation(BB2, y), |x-y|<6.28 -> type(Group, Corner)

Where BB = Bounding Box of a shape

In SPARQL:

CONSTRUCT { ?group rdf:type :Corner }

WHERE { ?transform1 o3d:in ?group , ?transform2 o3d:in ?group, ?plane1 o3d:in ?transform1, ?plane2 o3d:in ?transform2, ?plane1 o3d:rotation ?x, ?plane2 o3d:rotation ?y. FILTER (|x-y| < 6.28) }

Functional (Behavioral) semantic info

- Temporal info
- Interactivity (model to model and user to model)
- ………

Examples: quick, slow, first, second, animation path (linear, spline, easy-in-easy-out ….), user actions and interactions

Example query: TODO

Examples of implementations (functional semantics)

MPEG 7

What about different problem domains?

Each of the following working-group problem domains includes structured vocabularies and even ontologies.

- Medical
- Human Animation (HAnim)
- Computer Aided Design (CAD)
- 3D Printing
- 3D Scanning
- Cultural and Natural Heritage
- Building Information Modeling (BIM)
- Training and Education (e.g. SCORM)
-

Naming for different problem domains

How do we refer to these categories?

- We might use the formal names of each X3D component to avoid ambiguity
- When an external domain has a formal name/identifier, we can use that
- Is there a general Semantic Web approach we can follow?

Example #1 Moving a DECO owl ontology into X3D owl ontology

https://www.researchgate.net/publication/311694609_DECO_-DECoration_Ontology_Ontology_and_semantic_search_applications_for_support_in_interior_architecture_and_decoration_designs

Description of the DECO ontology in
https://drive.google.com/file/d/1jDLB4IpG4C9CWSQ2NNj9GtWNm9rfWApS/view?usp=sharing

And some details on how to implement SWRL queries in

https://drive.google.com/open?id=1UH4Dph93t1x6YSmvU1YOw3dpgTuOKEuH

And finally the ontology it self.

https://drive.google.com/open?id=1i0tZfq8xBC-dmungqSdekbu4r3BHqQ1K