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X3D Ontology for Querying 3D Models on the Semantic Web

Don Brutzman

Naval Postgraduate School (NPS)
Monterey, CA, USA
brutzman@nps.edu

Jakub Flotyński

Poznań University of Economics and Business, Poznań, Poland
flotynski@kti.ue.poznan.pl

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Topics

- X3D Semantic Web Working Group
- Motivations for semantic 3D content
- X3D Ontology and semantic models
- Queries to semantic X3D models
- Conclusions and future works

Motivation: Semantic Web

- "The proof of the pudding is in the eating." Wiktionary
- "Trying to use the Semantic Web without SPARQL is like trying to use a relational database without SQL." Tim Berners-Lee
- "The answer to your question is the response to the query." Jim Hendler and Dean Allemang

What if you can ask, and answer, any question?

Motivation: all 3D on the Web

- Many models are being produced through authoring tools, scanners, conversions etc.
- How do we keep track of this information?
  - Diverse data formats, irregular metadata
- How do we search for models of interest?
  - Common-denominator representation: X3D
  - Consistent, coherent metadata vocabularies
  - Unlock Semantic Web tools via X3D Ontology

Motivation: 3D/VR/AR on Web

Interestingly, all forms of presentation then have a consistent basis for query

- Content formats Extensible 3D (X3D) v4
- Integrating 3D/VR/AR with web browsers
- Wide access, collaborative environments
- Programming libraries, e.g., WebGL, Blender, Java, Python, JavaScript, others
- Device Interfaces, e.g., WebXR
- 3D printed models might be similarly accessed

Semantic Web

- Global database linking structured content with semantic descriptions
- Ontologies and knowledge bases
- Applicable to any domain and enables
  - Content description at arbitrary specification level
  - Reasoning
  - Queries
- W3C Standards: RDF, RDFS, OWL, SPARQL
- No common integration for 3D/VR/AR and Semantic Web

X3D Semantic Web Working Group

- Maximize interoperability with Semantic Web standards for greatest possible reuse and integration of 3D with the web
- Efficient indexing, search, comparison, and analysis of X3D models through the advanced use of metadata and semantics
- Create and partially autogenerate X3Dv4 OWL ontology from the X3D Unified Object Model (X3DUOM) using best-practice design patterns
- Support various Web3D Working Groups including Computer-Aided Design (CAD), 3D printing/scanning, Medical, Cultural and Natural Heritage, Humanoid Animation (HAnim) design work may consider other potential domains such as Building Information Models (BIM), etc.
- Build and maintain a list of domain-specific ontologies that are suitable for use in concert with the X3D Ontology.

Motivations for Semantic 3D Content

- Compliant with the current web evolution (semantic web)
- Facilitates
  - Management (indexing, searching)
  - Exploration (reasoning, queries)
  - Modeling (non-IT-specialists)

  of 3D content
- Independent of particular 3D formats and presentation platforms
- Different levels of specificity (3D and application/domain)
- Declarative content representation

Semantics of 3D Content: examples

- Semantic description of a 3D scene enables answers to semantic reasoning and queries about the scene
- Reasoning and queries may cover properties of 3D objects
  - At the 3D and domain levels of specificity
  - Related to different content features
    - Geometry, e.g.,
      - What is the type of a shape? (3D-specific)
      - What is the category of a car based on its shape? (domain-specific)
    - Structure, e.g.,
      - How many polygons does a 3D model have? (3D-specific)
      - What are components of a virtual car? (domain-specific)
    - Presentation, e.g.,
      - Which objects in a scene use a common texture? (3D-specific)
      - Which objects in a scene are made of wood? (domain-specific)
    - Behavior, e.g.,
      - What scripts describe the behavior of an object? (3D-specific)
      - What is the exercise performed by an avatar? (domain-specific)
- Combining specificity levels by ontology mapping, e.g., virtual museum ontology to 3D ontology

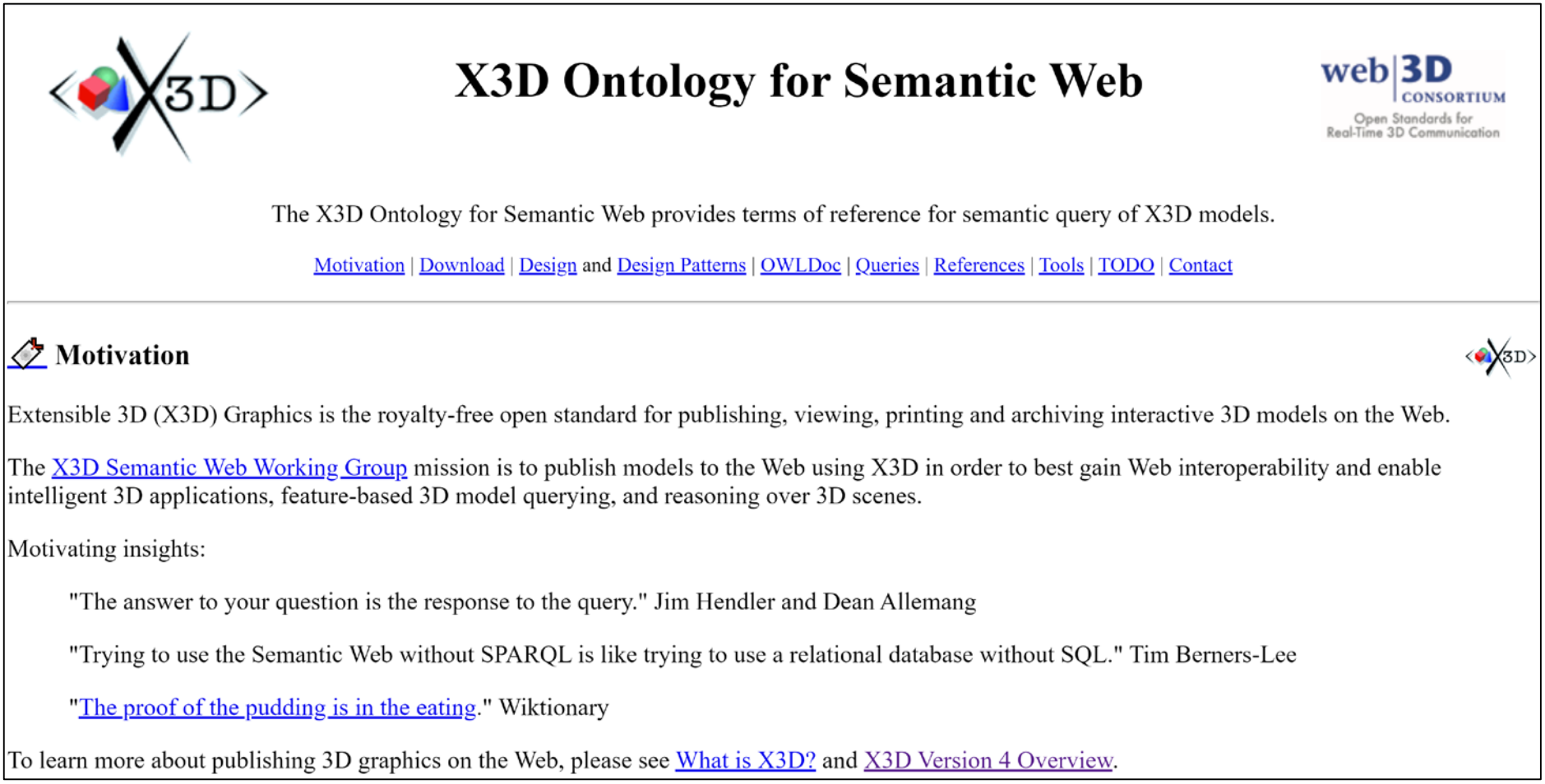
X3D Ontology

- Semantic representation of the X3D format
- Automatically generated from the X3D schema (XSLT)
- Encoded in TTL (match RDF, RDFS, OWL)
- Queryable with SPARQL
- Enables reasoning by concept combination

X3D Ontology

- Up-to-date representation of various 3D features
  - Geometry
  - Structure
  - Presentation
  - Animation
- Automatic generation of semantic X3D repositories upon the available content
- Reasoning and querying over the available X3D content

X3D Ontology website availability



X3D Ontology for Semantic Web

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Open Standards for Real-Time 3D Communication

The X3D Ontology for Semantic Web provides terms of reference for semantic query of X3D models.

Motivation | Download | Design and Design Patterns | OWLDoc | Queries | References | Tools | TODO | Contact

Motivation

Extensible 3D (X3D) Graphics is the royalty-free open standard for publishing, viewing, printing and archiving interactive 3D models on the Web.

The X3D Semantic Web Working Group mission is to publish models to the Web using X3D in order to best gain Web interoperability and enable intelligent 3D applications, feature-based 3D model querying, and reasoning over 3D scenes.

Motivating insights:

> "The answer to your question is the response to the query." Jim Hendler and Dean Allemang
>
> "Trying to use the Semantic Web without SPARQL is like trying to use a relational database without SQL." Tim Berners-Lee
>
> "The proof of the pudding is in the eating." Wiktionary

To learn more about publishing 3D graphics on the Web, please see What is X3D? and X3D Version 4 Overview.

https://www.web3d.org/x3d/content/semantics

Queries to Semantic X3D Models

Semantic Version of X3D Model

```
:X3D a owl:NamedIndividual, x3do:X3D ;
  x3do:hasHead :head ;
  x3do:hasScene :Scene ;
  x3do:profile 'Immersive' ;
  x3do:version '3.3' ;
  x3do:noNamespaceSchemaLocation
'http://www.web3d.org/specifications/x3d-3.3.xsd' .

:Scene a owl:NamedIndividual, x3do:Scene ;
  x3do:hasParent :X3D ;
  x3do:hasChildren :WorldInfo_2_1, :Background_2_2, :Group_2_3 .

:WorldInfo_2_1 a owl:NamedIndividual, x3do:WorldInfo ;
  x3do:hasParent :Scene ;
  x3do:title 'Hello World!' .

...
```

Queries to Semantic X3D Models

```
# Prefixes:
PREFIX rdf:  <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX owl:  <http://www.w3.org/2002/07/owl#>
PREFIX xsd:  <http://www.w3.org/2001/XMLSchema#>
PREFIX x3d:  <http://www.web3d.org/specifications/x3d-4.0.xsd#>
PREFIX x3do:
<http://www.web3d.org/specifications/X3dOntology4.0#>
```

now https://

```
# Query content:
SELECT ?WorldInfoNode ?title ?parentNode
WHERE
{
    ?WorldInfo rdf:type       x3do:WorldInfo ;
               x3do:title     ?title         ;
               x3do:hasParent ?parent .

    BIND (strafter(xsd:string(?WorldInfo),"#") AS ?WorldInfoNode)
    BIND (strafter(xsd:string(?parent),"#")    AS ?parentNode)
}
```

```
# Query result:
-------------------------------------------------
| WorldInfoNode   | title          | parentNode |
=================================================
| "WorldInfo_2_1" | "Hello World!" | "Scene"    |
-------------------------------------------------
```

Advanced query: ROUTE validity

- Test that ***event animation chains*** are fully connected with correct type, accessType

parentNode	RouteFound	fromNodeDEF	fromNodeTypeFound	fromField	toNodeDEF	toField
"Scene"	"ROUTE_2_5"	"OrbitalTimeInterval"	x3do:TimeSensor	"fraction_changed"	"SpinThoseThings"	"set_fraction"
"EarthCoordinateSystem"	"ROUTE_2_6_1"	"SpinThoseThings"	x3do:OrientationInterpolator	"value_changed"	"EarthCoordinateSystem"	"set_rotation"
"EarthCoordinateSystem"	"ROUTE_2_6_5"	"ClickTriggerTouchSensor"	x3do:TouchSensor	"touchTime"	"OrbitalTimeInterval"	"startTime"

Future possible queries:

- detect problems with missing triggers or connections, identify animation fragments
- Infer cause-and-effect relationships in model storyboard or User Experience (UX)

Areas of active future work

- Metadata and ontology correspondences
- ISO SC24 work on Geometry Ontology
- Shape recognition terms of reference
- 3D Printing metadata for materials, sizes, production, fit for purpose, etc. etc.
- Metadata for model format conversions, and X3D scene-graph format correspondences, to facilitate cross-format model search

Conclusions and Future Work

- Advantages of the presented approach
  - Integration of the semantic web and 3D
  - Up-to-date with X3D4
  - Automatic transformation
  - 3D representation for queries and reasoning rather than rendering
- Future work topics are numerous
  - Integration with achievements of other Web3D WGs
  - Transformation of other 3D formats (DFDL)
  - Mapping to domain ontologies

X3D Ontology for Querying 3D Models on the Semantic Web

Thank you for your attention

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semantics@web3d.org

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