Part 2: Query Examples

Semantic Web3D: Towards Comprehensive Representation of 3D Content on the Semantic Web

Part 2: Query Examples

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Presentation Outline

- X3D Semantic Web Working Group
- Motivations for Semantic 3D content
- The Semantic Web3D Approach
- X3D Ontology and Knowledge Bases
- Examples
- Conclusions and Future Work
3D/VR/AR on the Web

- Integration of 3D/VR/AR with Web browsers
- Wide accessibility and collaborative environments
- Content formats, e.g., Extensible 3D (X3D)
- Programming libraries, e.g., WebGL
- Interfaces, e.g., WebXR
The Semantic Web

- **Global database** linking structured content with semantic descriptions
- **Ontologies and knowledge bases**
- Applicable to **any domain**
- Enables
  - Content description at **arbitrary specification level**
  - Reasoning
  - Queries
- **W3C Standards**: RDF, RDFS, OWL, SPARQL
- No integration between 3D/VR/AR and the 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, 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 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
Example Semantics of 3D Content

- Semantic description of 3D scene enables **answers to semantic reasoning and queries about it**
- Reasoning and queries may cover properties of 3D objects
  - At both 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
The Semantic Web3D

• Current efforts of the working group
• Application of the semantic web to 3D technologies intended to support:
  – Development,
  – Management, and
  – Usage

… of 3D content on the web
Semantic Web3D

query-based domain-oriented content creation, information retrieval, validating 3D content

Ontology-based 3D Content Representation

Ontologies

Domain specificity level
- a domain ontology
  - is instance of
  - a domain knowledge base

The Mapping Meta-Ontology
- is instance of
- a mapping ontology
  - is instance of
  - a mapping knowledge base

3D specificity level
- a 3D ontology (e.g., the X3D Ontology)
  - is instance of
  - a 3D knowledge base (e.g., an X3D knowledge base)

Queries

Meta queries
- domain-specific queries
- SPARQL queries
- RDF/RDFS/OWL queries

Concrete queries
- 3D-specific queries

knowledge-based 3D modeling

XSLT/DFDL transformation

The X3D Unified Object Model (X3DUOM) / another 3D format schema
- is instance of
- an X3D model or scene / a 3D model or scene in another format

3D content schema

3D content XSLT/DFDL transformation

activities on 3D content

data links

Domain-oriented 3D content creation

Discovering domain knowledge

query-based 3D modeling and editing, information retrieval, validating 3D content
3D Content and Transformations

3D specificity level

- a 3D ontology (e.g., the X3D Ontology)

3D content schema
XSLT/DFDL transformation

knowledge-based 3D modeling

The X3D Unified Object Model (X3DUOM) / another 3D format schema

is instance of

a 3D knowledge base (e.g., an X3D knowledge base)

3D content
XSLT/DFDL transformation

an X3D model or scene / a 3D model or scene in another format

is instance of

3D modeling
X3D Ontology

- Semantic representation of the X3D format
- Automatically generated from the X3D Unified Object Model (X3DUOM) via XSLT
- Encoded in RDF, RDFS, OWL
- Queryable with SPARQL
- Enables reasoning
Advantages

• **Up-to-date** representation of various 3D features
  – Geometry
  – Structure
  – Presentation
  – Animation

• **Automatic generation** of semantic X3D repositories based on already-available 3D models

• **Reasoning and querying** over transcribed versions of available X3D content
Example: San Carlos Cathedral

https://x3dgraphics.com/examples/X3dForAdvancedModeling/SanCarlosCathedral

https://upload.wikimedia.org/wikipedia/commons/c/c1/Monterey%2C_California_-_Cathedral_of_San_Carlos_Borromeo%28Royal_Presidio_Chapel%29_-_panoramio.jpg

Example: San Carlos Cathedral

https://x3dgraphics.com/examples/X3dForAdvancedModeling/SanCarlosCathedral

X3D Example Archives: X3D for Advanced Modeling, San Carlos Cathedral, San Carlos Cathedral

San Carlos Cathedral is the oldest continuously functioning church and the first stone building in the State of California.

<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE X3D PUBLIC "-//Web3D//DTD X3D 3.3//EN" "http://www.web3d.org/specifications/x3d-3.3.dtd">
<X3D profile="Immersive" version="3.3" xmlns:xsd="http://www.w3.org/2001/XMLSchema-instance" xmlns:noNamespaceSchemaLocation="http://www.web3d.org/specifications/x3d-3.3.xsd">
  <head>
    <meta name="title" content="SanCarlosCathedral.x3d" />
    <meta name="description" content="San Carlos Cathedral is the oldest continuously functioning church and the first stone building in the State of California." />
    <meta name="creator" content="Michele Foti, Don Brutzman" />
    <meta name="created" content="15 December 2011" />
    <meta name="modified" content="5 December 2014" />
    <meta name="reference" content="documentation" />
    <meta name="reference" content="tests" />
  </head>
Cathedral: semantic representation

```turtle
# Prefixes: 'x3do', ':', 'rdf' and 'owl' indicate: the X3D Ontology and knowledge base as well as RDF and OWL.

:scene rdf:type owl:NamedIndividual , x3do:Scene .
:scene x3do:hasBackground :background .
:background rdf:type owl:NamedIndividual, x3do:Background; x3do:skyColor (0.7216 0.8 0.9922).
:scene x3do:hasTransform :Colonna1 .
:Colonna1 rdf:type owl:NamedIndividual , x3do:Transform ; x3do:translation (0.7 0 -0.7) .
:Colonna1 x3do:hasShape :woodenElement1 .
:woodenElement1 rdf:type owl:NamedIndividual , x3do:Shape.
:woodenElement1 x3do:hasBox :woodenElement1Box .
:woodenElement1Box rdf:type owl:NamedIndividual, x3do:Box; x3do:size (0.4 1.2 0.4) .
:woodenElement1 x3do:hasAppearance :WoodAppearance .
:WoodAppearance x3do:hasTexture :Wood .
```
Cathedral: SPARQL semantic query 1

# Prefixes: 'x3do', ':', 'rdf' and 'owl' indicate: the X3D Ontology and knowledge base as well as RDF and OWL.

:scene rdf:type owl:NamedIndividual , x3do:Scene .
:scene x3do:hasBackground :background .
:background rdf:type owl:NamedIndividual, x3do:Background;
   x3do:skyColor (0.7216 0.8 0.9922).
:scene x3do:hasTransform :Colonna1 .
:Colonna1 rdf:type owl:NamedIndividual , x3do:Transform ;
   x3do:translation (0.7 0 -0.7) .
:Colonna1 x3do:hasShape :woodenElement1 .
:woodenElement1 rdf:type owl:NamedIndividual , x3do:Shape .
:woodenElement1 x3do:hasBox :woodenElement1Box .
:woodenElement1Box rdf:type owl:NamedIndividual, x3do:Box;
  x3do:size (0.4 1.2 0.4) .
:woodenElement1 x3do:hasAppearance :WoodAppearance .

How many shapes together compose the altar?

```
SELECT (count(distinct ?shape) as ?num) WHERE {
  ?shape rdf:type x3do:Shape . }
```
Perform X3D Ontology query X3dSanCarlosCathedralAltarQuery_01.rq using examples/Altar.ttl to produce output file X3dSanCarlosCathedralAltarQuery_01.rq.txt:

```
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/semantics/ontologies/X3dOntology4.0#>

# X3dSanCarlosCathedralAltarQuery_01.rq  Query Altar.ttl to count numberShapes

# Every X3D knowledge base can be subject to semantic queries.

# The following SPARQL query provides the number of shapes composing the altar.
# The result of the query is: 14.

SELECT (count(distinct ?shape) as ?numberShapes)

WHERE
{
    ?shape rdf:type x3do:Shape .
}

<table>
<thead>
<tr>
<th>numberShapes</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
</tr>
</tbody>
</table>
```
Cathedral: SPARQL semantic query 2

```
# Prefixes: 'x3do', ':', 'rdf' and 'owl' indicate: the X3D
  Ontology and knowledge base as well as RDF and OWL.

:scene rdf:type owl:NamedIndividual , x3do:Scene .
:scene x3do:hasBackground :background .
:background rdf:type owl:NamedIndividual, x3do:Background;
  x3do:sunColor (0.7216 0.8 0.9922).
:scene x3do:hasTransform :Colonna1 .
:Colonna1 rdf:type owl:NamedIndividual , x3do:Transform ;
  x3do:translation (0.7 0 -0.7) .
:Colonna1 x3do:hasShape :woodenElement1 .
:woodenElement1 rdf:type owl:NamedIndividual , x3do:Shape.
:woodenElement1 x3do:hasBox :wo-
:woodenElement1Box rdf:type owl:
  x3do:size (0.4 1.2 0.4) .
:woodenElement1 x3do:hasAppearance.
:WoodAppearance rdf:type owl:Na-
  Appearance .
:WoodAppearance x3do:hasTexture
:Wood rdf:type owl:NamedIndividual , x3do:ImageTexture ;
  x3do:url ".../Wood.jpg" .
```

What textures are used for the 3D model?

SELECT ?textureUrl WHERE {
  ?x x3do:hasTexture ?texture .
} ORDER by ASC(?textureUrl)
Perform X3D Ontology query X3dSanCarlosCathedralAltarQuery_02.rq using examples/Altar.ttl to produce output file X3dSanCarlosCathedralAltarQuery_02.rq.txt:

```
# (PREFIX headers omitted)

# X3dSanCarlosCathedralAltarQuery_02.rq    Query Altar.ttl for texture url values.
# Every X3D knowledge base can be subject to semantic queries.

# The following query provides the url addresses of all textures used within the scene.
# The result is the wood texture: ../Wood.jpg (cf. Listing 3, line 18)

SELECT ?appearanceNode ?textureUrl
WHERE
{
    ?appearance x3do:hasTexture ?texture .

    BIND (strafter(xsd:string(?appearance),"#") AS ?appearanceNode)
}
ORDER by ASC(?textureUrl)
```

<table>
<thead>
<tr>
<th>appearanceNode</th>
<th>textureUrl</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;WoodAppearance&quot;</td>
<td>&quot;\images/Wood.jpg&quot;</td>
</tr>
<tr>
<td>&quot;<a href="https://x3dgraphics.com/examples/X3dForAdvancedModeling/SanCarlosCathedral/images/Wood.jpg">https://x3dgraphics.com/examples/X3dForAdvancedModeling/SanCarlosCathedral/images/Wood.jpg</a>&quot;</td>
<td></td>
</tr>
</tbody>
</table>
Cathedral: SPARQL semantic query 3

```sparql
# Prefixes: 'x3do', ':', 'rdf' and 'owl' indicate: the X3D Ontology and knowledge base as well as RDF and OWL.

:scene rdf:type owl:NamedIndividual , x3do:Scene .
:scene x3do:hasBackground :background .
:background rdf:type owl:NamedIndividual, x3do:Background;
x3do:sunnyColor (0.7216 0.8 0.9922).
:scene x3do:hasTransform :Colonnal .
:Colonnal rdf:type owl:NamedIndividual, x3do:Transform;
x3do:translation (0.7 0 -0.7) .
:Colonnal x3do:hasShape :woodenElement1 .
:woodenElement1 rdf:type owl:NamedIndividual, x3do:Shape.
:woodenElement1 x3do:hasBox :woodenElement1Box .
:woodenElement1Box rdf:type owl:NamedIndividual, x3do:Box;
x3do:size (0.4 1.2 0.4) .
:woodenElement1 x3do:hasAppearance :WoodAppearance .
:WoodAppearance x3do:hasTexture :Wood .
:Wood rdf:type owl:NamedIndividual, x3do:ImageTexture;
x3do:url ".../Wood.jpg" .

SELECT ?skyColorListVal WHERE {
  ?background rdf:type x3do:Background ;
}
```

What is the sky color?

Query and result
Perform X3D Ontology query X3dSanCarlosCathedralAltarQuery_03.rq using examples/Altar.ttl to produce output file X3dSanCarlosCathedralAltarQuery_03.rq.txt:

# (PREFIX headers omitted)

# X3dSanCarlosCathedralAltarQuery_03.rq    Query Altar.ttl to determine Background skyColor values.

```
# Every X3D knowledge base can be subject to semantic queries.
# The following query retrieves the Background skyColor used in the scene.
# The result is the following list of RGB values: (0.7216 0.8 0.9922) (cf. Listing 3, line 6).
# Note special handling of RDF lists:
# Bob DuCharme's weblog, 21 April 2014, "RDF lists and SPARQL"

SELECT ?backgroundNode ?skyColorListValues
WHERE
{
  ?background rdf:type x3do:Background ;
  BIND (strafter(xsd:string(?background),"#") AS ?backgroundNode)
  # TODO re-aggregate skyColor list values into list of tuples
}
```

<table>
<thead>
<tr>
<th>backgroundNode</th>
<th>skyColorListValues</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Background_2_2&quot;</td>
<td>0.7216</td>
</tr>
<tr>
<td>&quot;Background_2_2&quot;</td>
<td>0.8</td>
</tr>
<tr>
<td>&quot;Background_2_2&quot;</td>
<td>0.9922</td>
</tr>
</tbody>
</table>
Conclusions and Future Work

• Advantages of the presented approach
  – Integration of the Semantic Web and 3D
  – Up-to-date with all versions of X3D
  – Automatic generation of ontology eliminates potential errors
  – Queries and reasoning become feasible, consistent
  – Platform-independent

• Future work
  – Integration with achievements of other Web3D Working Groups
  – Integration with metadata and semantics in X3D metadata nodes
  – Mapping to diverse domain ontologies
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Thank you for your attention

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