Towards Better Co-Design with Disciplinary Ontologies: Review and Evaluation of Data Interoperability in the AEC Industry

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• **Background and motivation**

• **Review of key approaches to the interoperability problem**
  • Data schemas and frameworks for interoperability
  • Linked data and ontologies

• **Evaluation and proposal**
  • Comparison of interoperability approaches
  • How ontologies can support collaborative design tools
  • Proposal: Using disciplinary ontologies with BHoM

• **Conclusion**
What is a column?  
the answer depends on whom we ask
Multi-disciplinarity in co-designing buildings

"All models are wrong, but some are useful"

George E. P. Box

Design Phases and Decisions

The most critical design decisions happen in the early stages of design. These decisions influence:

- Construction costs
- Subsequent building energy use

The Research Areas
Methods: Truly integrative computational design and engineering methods
Processes: Robotic cyber-physical fabrication and construction processes
Systems: Genuinely digital, next-generation material and building systems
Cross Sectoral: Inclusive and sustainable innovation with critical reflection
Demonstrators: Rapid turn from visionary research to architectural application

The Research Units
Architecture
Structural Engineering, Building Physics and Geodesy
Manufacturing and Systems Engineering
Computer Science and Robotics
Humanities and Social Sciences
Data Interoperability

Data schemas and frameworks for interoperability
Data schemas and frameworks for interoperability

IFC

- Is a standardized data schema for the AEC industry based on the EXPRESS data model;
- Represents data in a monolithic approach;
- Powerful in representing/documenting element classification and product properties, but it falls when representing dynamic data;
Data schemas and frameworks for interoperability

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**SPECKLE**

- Open source, web-based collaborative framework
- Offers a neutral schema for the specification and creation of basic geometry types
- Around 150 object models, and numerous connectors to design software
**Data schemas and frameworks for interoperability**

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- **SPECKLE**
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- **BHoM**
  - Open source, collaborative framework
  - Offers multiple, discrete disciplinary representations of building elements, therefore it has a rich object model library with over 1200 object models.
  - It separates objects from functions; consists of (1) object models, (2) engines that operate on data, (3) adapters that map and translate data among different software and (4) user interfaces for software where its functionality is exposed.
Linked Data and Ontologies

W3C standard data model: RDF

Subject -> predicate -> Object

Linked Building Data (LBD) community group/ AEC ontologies

Semantic Web technologies remains one of the most promising solutions to link data from heterogenous systems.

Building Topology Ontology BOT  
IFC represented in OWL ifcOWL  
Brick Schema
Interoperability Approaches

(a) distributed

(b) centralized

(c) federated

Distributed interoperability
Centralized interoperability
Federated interoperability
Federated interoperability

Source: Fischer A. et al. (2021) Buildings and Habitats object Model, github.com/BHoM
Federated interoperability

Common object Model (oM)  
How to represent a “Wall”

- Physical: BH.oM.Physical.Elements.Wall
- Geometrical: BH.oM.Geometry, PlanarSurface, BH.oM.Geometry, NurbsSurface, BH.oM.Geometry, NurbsCurve
- Graphical: BH.oM.Graphics, RenderMesh

Source: BHoM, github.com/BHoM
Federated interoperability

Common object Model (oM)
How to represent a "Wall"

Physical  BH.oM.Physical.Elements.Wall
Analytical BH.oM.Facade.Elements.Panel
          BH.oM.Structure.Elements.Panel
          BH.oM.Environment.Elements.Panel
Geometrical BH.oM.Geometry.PlaneSurface
          BH.oM.Geometry.NurbsSurface
          BH.oM.Geometry.NurbsCurve
Graphical  BH.oM.Graphics.RenderMesh

Objects are mapped, not linked. BHoM lacks a shared ontology

Source: BHoM, github.com/BHoM
How ontologies can support collaborative design tools

- Connect concepts
- Augment building elements with semantic information

physical oM Column

```csharp
public virtual ICurve Location { get; set; } = new Polyline();
public virtual IFramingElementProperty Property { get; set; } = null;
```

structural oM Bar

```csharp
public virtual Node StartNode { get; set; }
public virtual Node EndNode { get; set; }
public virtual ISectionProperty SectionProperty { get; set; } = null;
public virtual double OrientationAngle { get; set; } = 0;
public virtual BarRelease Release { get; set; } = null;
public virtual BarFEAType FEAType { get; set; } = BarFEAType.Flexural;
public virtual Constraint4DOF Support { get; set; } = null;
public virtual Offset Offset { get; set; } = null;
```
How ontologies can support collaborative design tools

- Connect concepts
- Augment building elements with semantic information

```
bhom:Column owl:sameAs bhom:Bar.
Bhom:lineStartNode owl:sameAs bhom:barStartNode
```
How ontologies can support collaborative design tools

- Connect concepts
- Augment/annotate building elements with semantic information

- Design building elements with design tools (Rhino 3D, grasshopper 3D, Revit, etc.); and
- Augment them with semantic information using ontologies.

Such function should be integrated in design tools. BHoM allows such an approach, by also allowing extending data dictionaries, directly while designing.
How ontologies can support collaborative design tools

- Connect concepts
- Augment/annotate building elements with semantic information
- Powerful queries
- Add rules, validate data, reasoning

has_material  
has_color  
is_located  
etc.
Proposal: Using disciplinary ontologies with BHoM

Future Work

• convert BHoM’s data model to OWL

• develop disciplinary ontologies with BHoM object models, as modular ones aligned with existing ontologies like BOT, TDY, etc.
Come join us in Stuttgart!
We are looking for a Computer Science Ph.D. Student to work in Knowledge Graphs and Semantic Web.