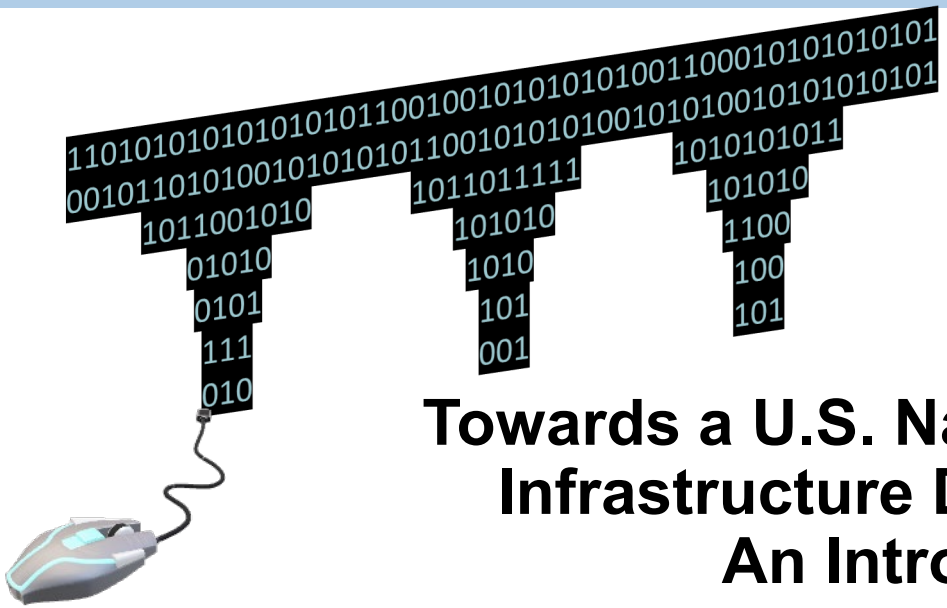


Towards a U.S. National Bridge and Infrastructure Data Dictionary: An Introduction

Aaron Costin, Ph.D., University of Florida, USA
Marina Muller, Ph.D., Florida Gulf Coast University, USA

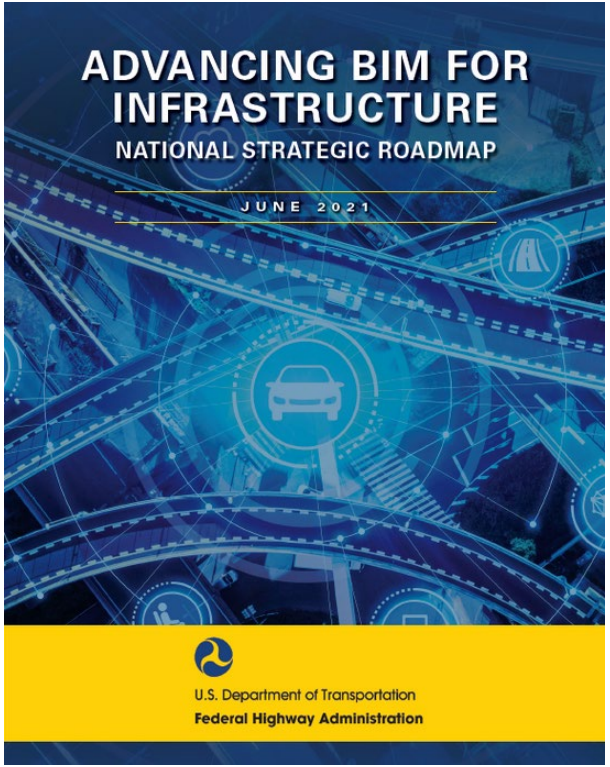
11th Linked Data in Architecture and Construction Workshop
15 - 16 June 2023

Agenda

- Background and Motivation
- Challenge
- Related Works
- Research Aim and Goals
- Proposed solution: Automated Data Dictionary Mapping
- Open Challenge

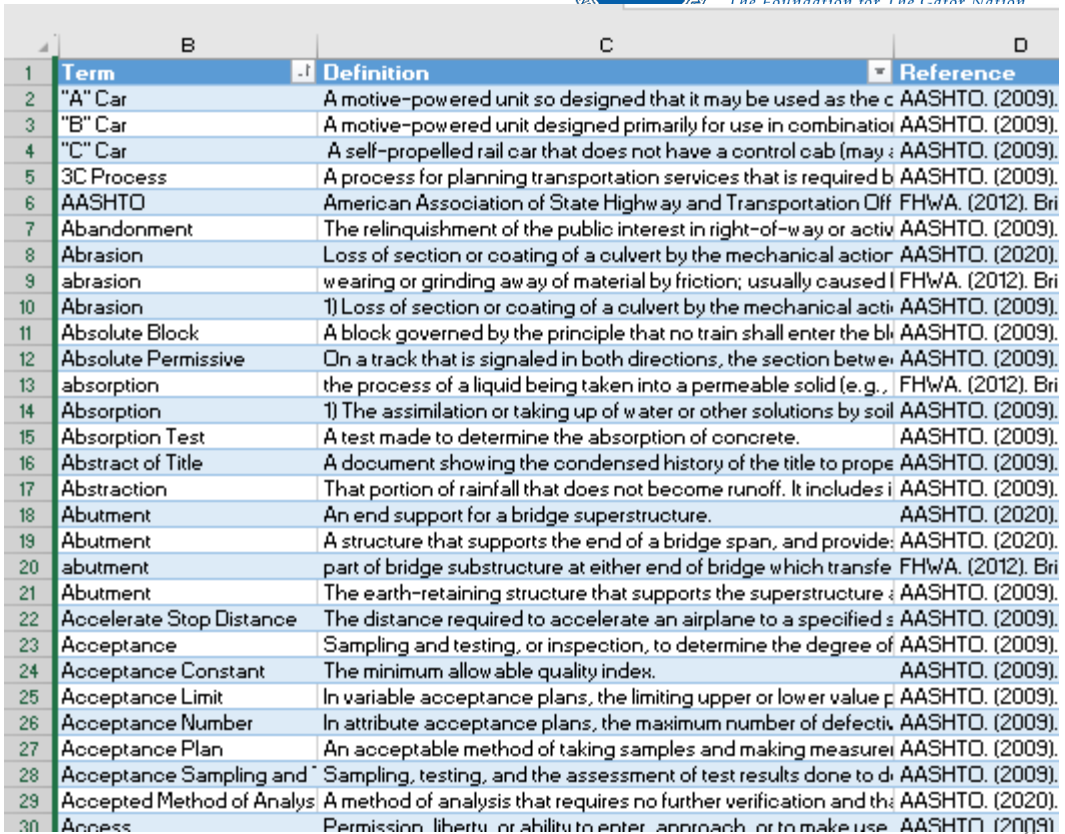
Background and Motivation

- Push in the U.S. to define a national BIM for bridge and infrastructure standard
- Adoption industry foundation classes (IFC) as the standard data schema
  - for the exchange of electronic engineering data
- Coordinated effort to integration BIM and IFC into transportation workflows
- Need for a standard U.S. bridge and infrastructure knowledge base



Challenge

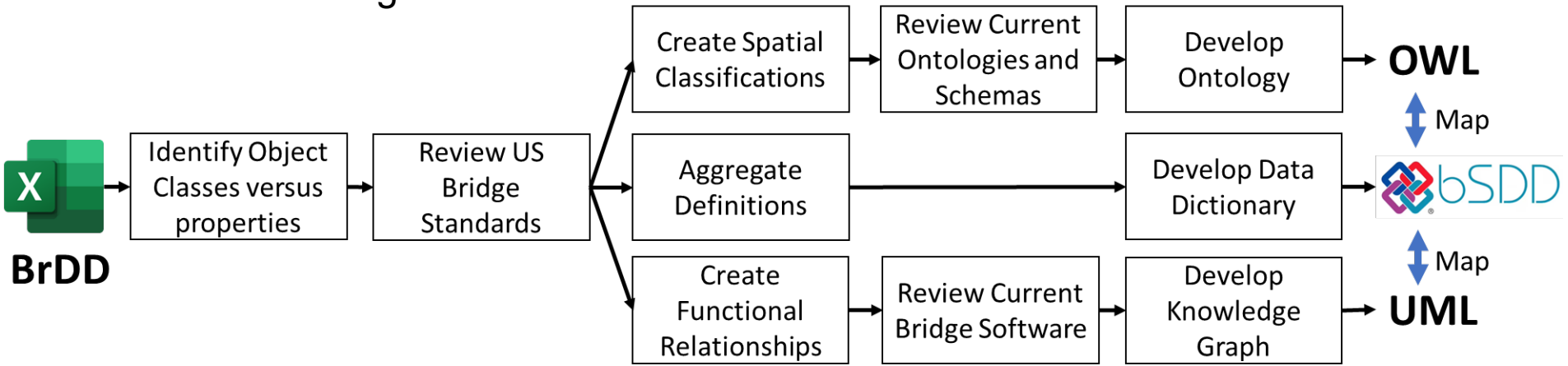
- Lack of a consistent U.S. bridge knowledge base
- Inconsistent and conflicting data
- Gap in industry experts and software/technical developers
- Coordination between the various efforts



	B	C	D
1	Term	Definition	Reference
2	"A" Car	A motive-powered unit so designed that it may be used as the c	AASHTO. (2009).
3	"B" Car	A motive-powered unit designed primarily for use in combinatio	AASHTO. (2009).
4	"C" Car	A self-propelled rail car that does not have a control cab (may	AASHTO. (2009).
5	3C Process	A process for planning transportation services that is required b	AASHTO. (2009).
6	AASHTO	American Association of State Highway and Transportation Off	FHWA. (2012). Bri
7	Abandonment	The relinquishment of the public interest in right-of-way or activ	AASHTO. (2009).
8	Abrasion	Loss of section or coating of a culvert by the mechanical actior	AASHTO. (2020).
9	abrasion	wearing or grinding away of material by friction; usually caused	FHWA. (2012). Bri
10	Abrasion	1) Loss of section or coating of a culvert by the mechanical acti	AASHTO. (2009).
11	Absolute Block	A block governed by the principle that no train shall enter the bl	AASHTO. (2009).
12	Absolute Permissive	On a track that is signaled in both directions, the section betwe	AASHTO. (2009).
13	absorption	the process of a liquid being taken into a permeable solid (e.g.,	FHWA. (2012). Bri
14	Absorption	1) The assimilation or taking up of water or other solutions by soil	AASHTO. (2009).
15	Absorption Test	A test made to determine the absorption of concrete.	AASHTO. (2009).
16	Abstract of Title	A document showing the condensed history of the title to prope	AASHTO. (2009).
17	Abstraction	That portion of rainfall that does not become runoff. It includes i	AASHTO. (2009).
18	Abutment	An end support for a bridge superstructure.	AASHTO. (2020).
19	Abutment	A structure that supports the end of a bridge span, and provide:	AASHTO. (2020).
20	abutment	part of bridge substructure at either end of bridge which transfe	FHWA. (2012). Bri
21	Abutment	The earth-retaining structure that supports the superstructure a	AASHTO. (2009).
22	Accelerate Stop Distance	The distance required to accelerate an airplane to a specified s	AASHTO. (2009).
23	Acceptance	Sampling and testing, or inspection, to determine the degree of	AASHTO. (2009).
24	Acceptance Constant	The minimum allowable quality index.	AASHTO. (2009).
25	Acceptance Limit	In variable acceptance plans, the limiting upper or lower value p	AASHTO. (2009).
26	Acceptance Number	In attribute acceptance plans, the maximum number of defecti	AASHTO. (2009).
27	Acceptance Plan	An acceptable method of taking samples and making measure	AASHTO. (2009).
28	Acceptance Sampling and	Sampling, testing, and the assessment of test results done to d	AASHTO. (2009).
29	Accepted Method of Analys	A method of analysis that requires no further verification and th	AASHTO. (2020).
30	Access	Permission, liberty, or ability to enter, approach, or to make use	AASHTO. (2009)

Research Aim and Goals

- Create a bridge and infrastructure data dictionary
- Single source of truth
- Extend to ontological models



Related Works – IFC

- IFC 4.3[1]- multiple civil infrastructure updates
  - Limitations for full bridge representation
  - E.g., Only 10 defined spatial elements
- IFC for finite element analysis (FEA) *(Shishlov et al. 2023)*
- 3D alignment expansion for railways *(Kwon et al 2020)*
- buildingSMART Data Dictionary (bSDD) [2]

[1] https://ifc43-docs.standards.buildingsmart.org/

[2] https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/

Related Works – Bridge Ontology

- BrMontology ontological knowledgebase for bridge maintenance *(Ren et al. 2019)*
- Bridge Ontology Architecture for Knowledge Management in Bridge Maintenance *(Banujan and Vasanthapriyan (2020)*
- Bridge Topology Ontology (BROT) *(Hamdan et al. 2020)*
  - Bridge Components Ontology (BRCOMP)
  - Building Material Ontology (BMAT)
  - Bridge Structure Ontology (BRSTR)
  - Bridge Classification Ontology (BRIDGE).
- Ontology for bridge inspection (ASB-ING Ontology) *(Göbels and Beetz 2021)*

Data Dictionary

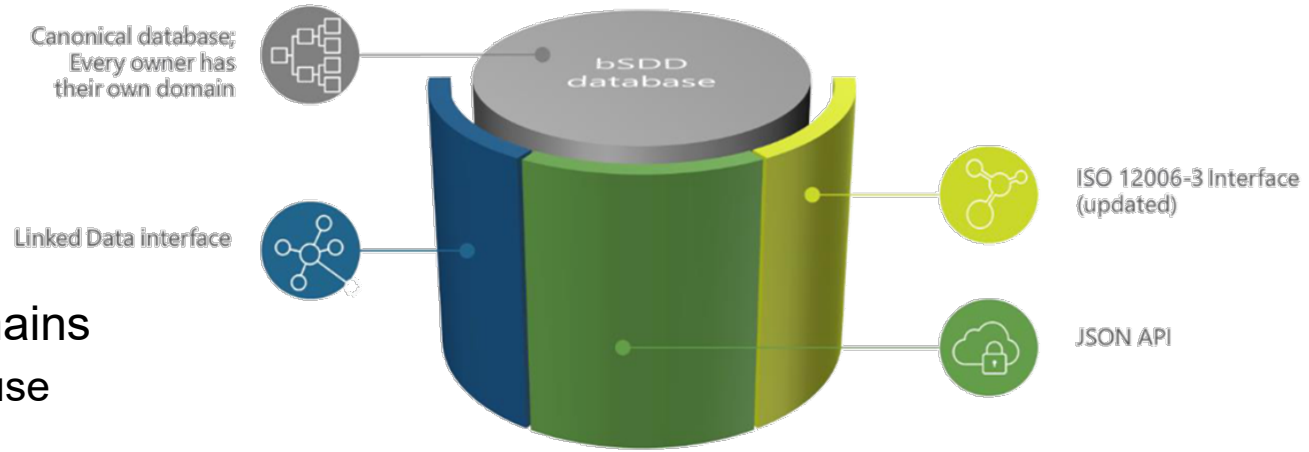
- *Centralized repository of information about data such as meaning, relationships to other data, origin, usage, and format*[1]

  - Used to catalog and communicate the structure and content of data
  - Provides meaningful descriptions for individually named data objects
  - Gives context to the data being stored

[1] *IBM Dictionary of Computing,* McGraw-Hill Education - Europe; 10th edition (August 1, 1993)

US Data Dictionary

- Part of the buildingSMART International Data Dictionary (bSDD)
  - Incorporates the industry foundation classes (IFC) and other bSI technologies
  - Accepted internationally
- Defined the US based definitions
  - Collaboration among domain organizations
- Can host multiple domains
  - Enable linkages for reuse



via "Technical Roadmap buildingSMART", April 2020

Data Dictionary Example: Bridge

UF UNIVERSITY of FLORIDA
The Foundation for The Gator Nation

buildingSMART
International home of openBIM

Domain Metadata

Owners/Stewards

Field	DataType	Required	Translatable	Description
OrganizationName	Text	Yes	No	buildingSMART International
DomainName	Text	Yes	No	IFC
DomainVersion	Text	Yes	No	2.2
VersionDate	Date	No	No	2017-10-01
LanguageCode	Text	Yes	No	de-DE
LanguageOnly	Boolean	Yes	No	yes
License	Text	No	No	No license

Property Metadata

Data specification

Field	DataType	Required	Translatable	Description
Id	Text	Yes	No	ifc-99088-01
PropertyName	Text	Yes	Yes	IsExternal
ClassificationId	Text	Yes	No	ifc-00123-01
Dimension	Text	No	No	1 0 -2 0 0 0 0
MethodOfMeasurement	Text	No	Yes	Thermal transmittance
DataType	Text	No	No	integer

Classifications Metadata

clarifications

Field	DataType	Required	Translatable	Description
Id	Text	Yes	No	ifc-00123-01
ClassificationName	Text	Yes	Yes	IfcBridge
Definition	Text	No	Yes	A Bridge is civil ..
Status	Text	No	No	Active
DocumentReference	Text	No	No	ISO 6707 1 2014
CountryOfOrigin	Text	No	No	DE
CountriesOfUse	Text	No	No	EN;NL;DE
SubdivisionsOfUse	Text	No	Yes	US-MT
ClassificationType	Text	No	No	ComposedProperty

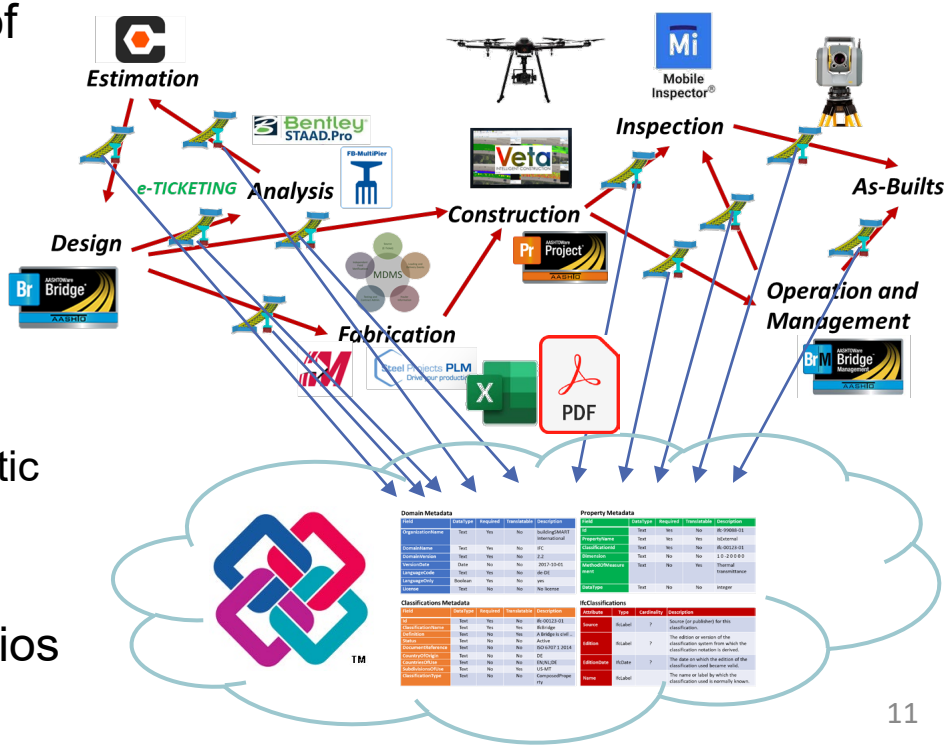
IfcClassifications

Domain specific data

Attribute	Type	Cardinality	Description
Source	IfcLabel	?	Source (or publisher) for this classification.
Edition	IfcLabel	?	The edition or version of the classification system from which the classification notation is derived.
EditionDate	IfcDate	?	The date on which the edition of the classification used became valid.
Name	IfcLabel		The name or label by which the classification used is normally known.

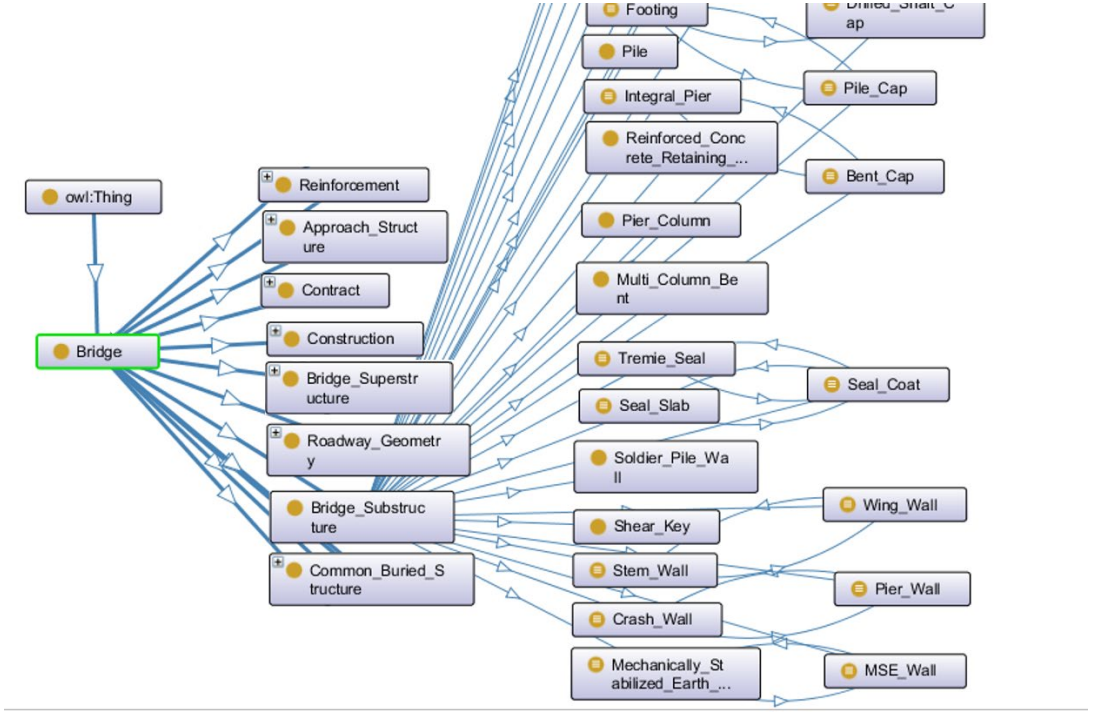
Why the Data Dictionary?

- Defines the structure and the meaning of concepts and terms
  - Ensures their consistent use by all stakeholders over the life cycle of a construction
- Efficient way to organize knowledge for subsequent retrieval
  - Querying the Semantic Web.
  - BIM and web-based context for the semantic annotation of model object
- Further enhance exchange and interoperability in data exchange scenarios



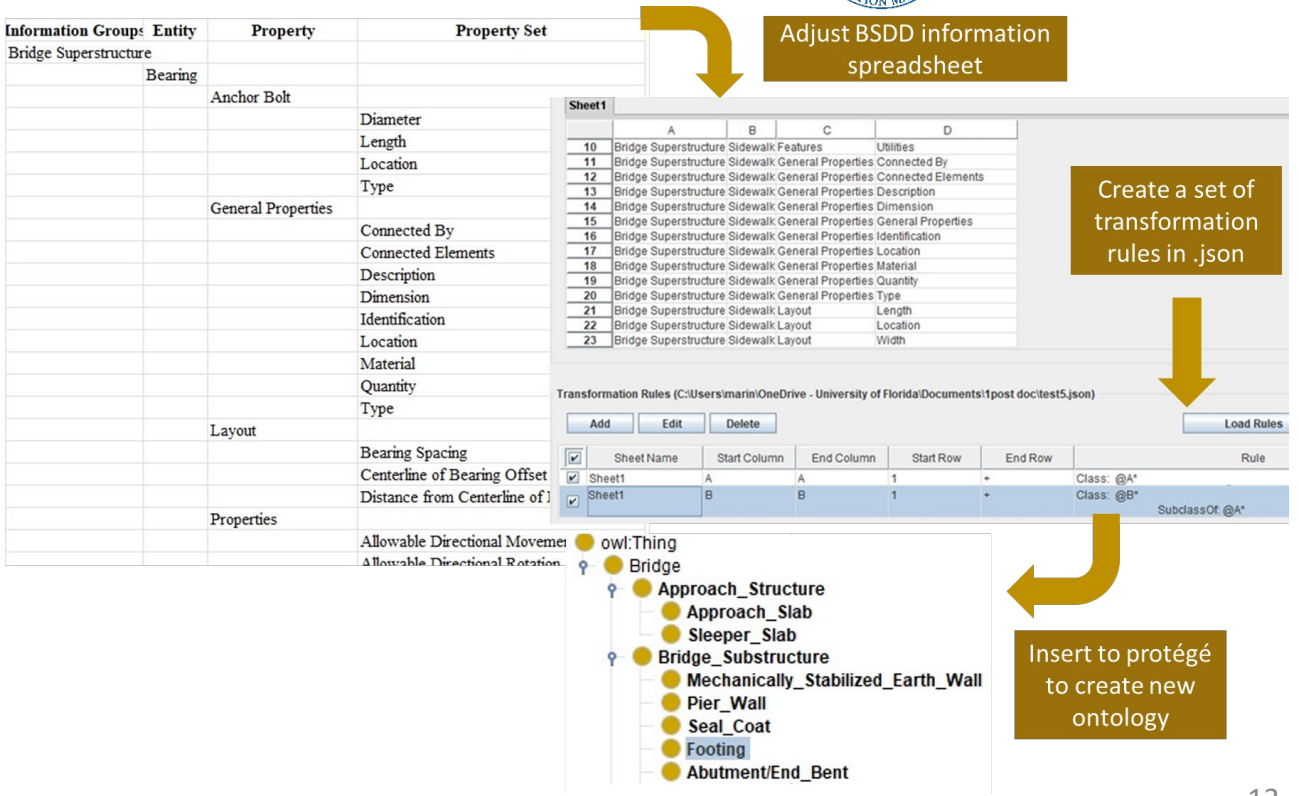
Issues with Current US Data

- Spatial hierarchy vs functional hierarchy
- Excel and PDF Based
- Missing Terms
- No national infrastructure classification system



How do we get there?

- Approach #1: Manual Mapping to bSDD
- Approach #2: Map the terminology to .owl then to bSDD
- Both have limitations and challenges
- Need an Automated Approach that goes bi-directional

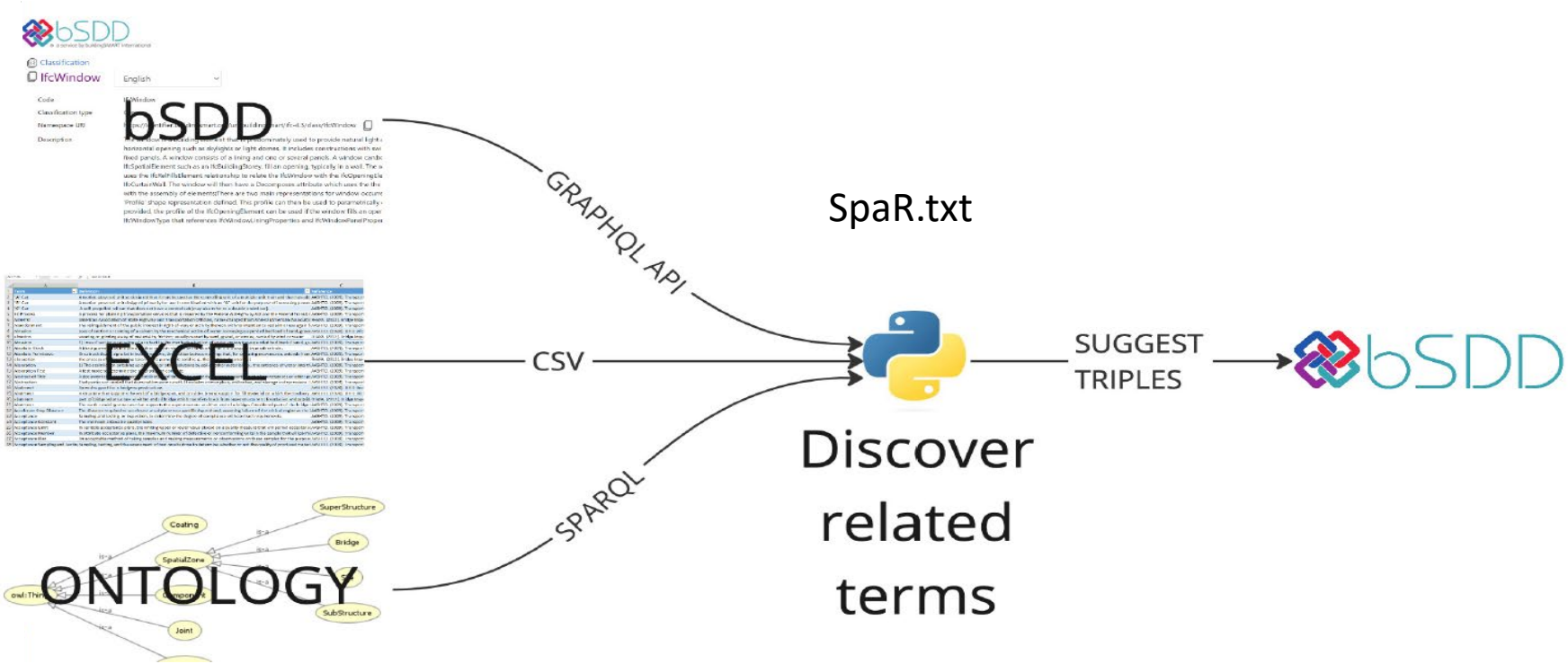


Research Update

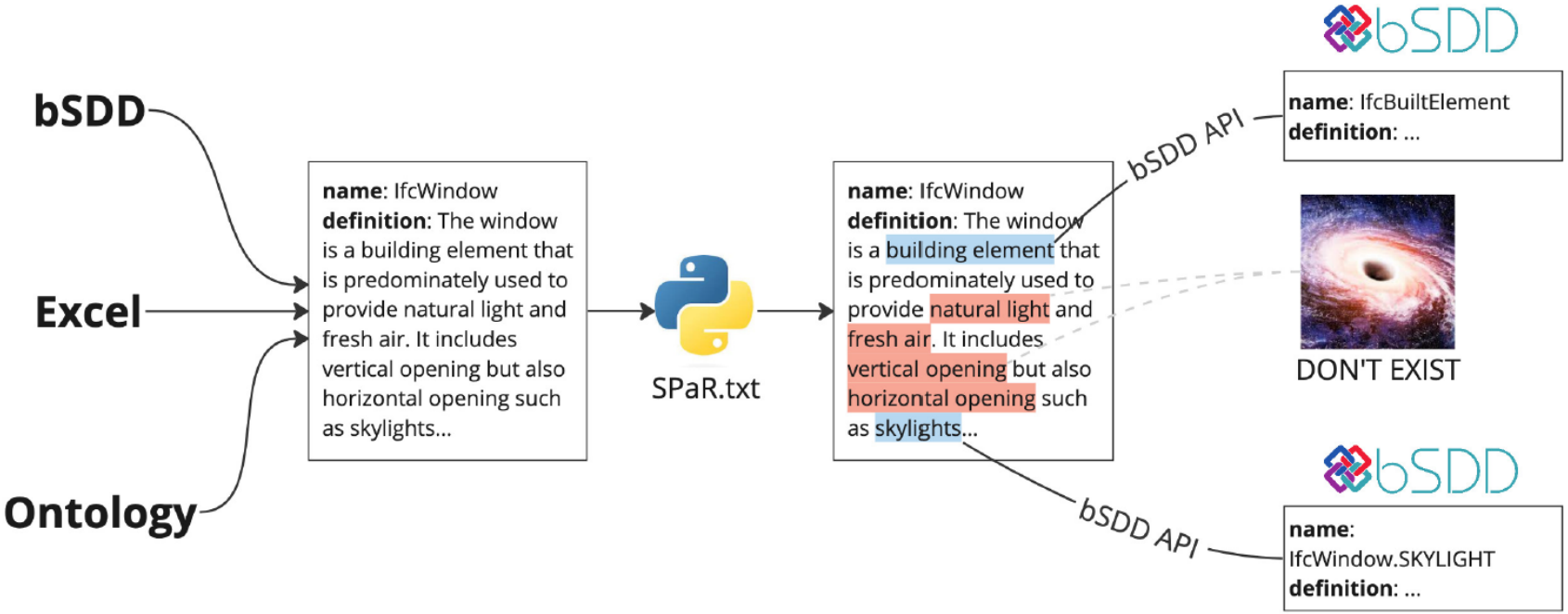
- LDAC 2023 Hackathon
  - Artur Tomczak
  - Rueben Kruiper
  - Giulia Maslov
  - Rebekka Benfer
  - Aaron Costin
- Challenge: How to automate the linking to similar terms and properties

be aS Do Dos

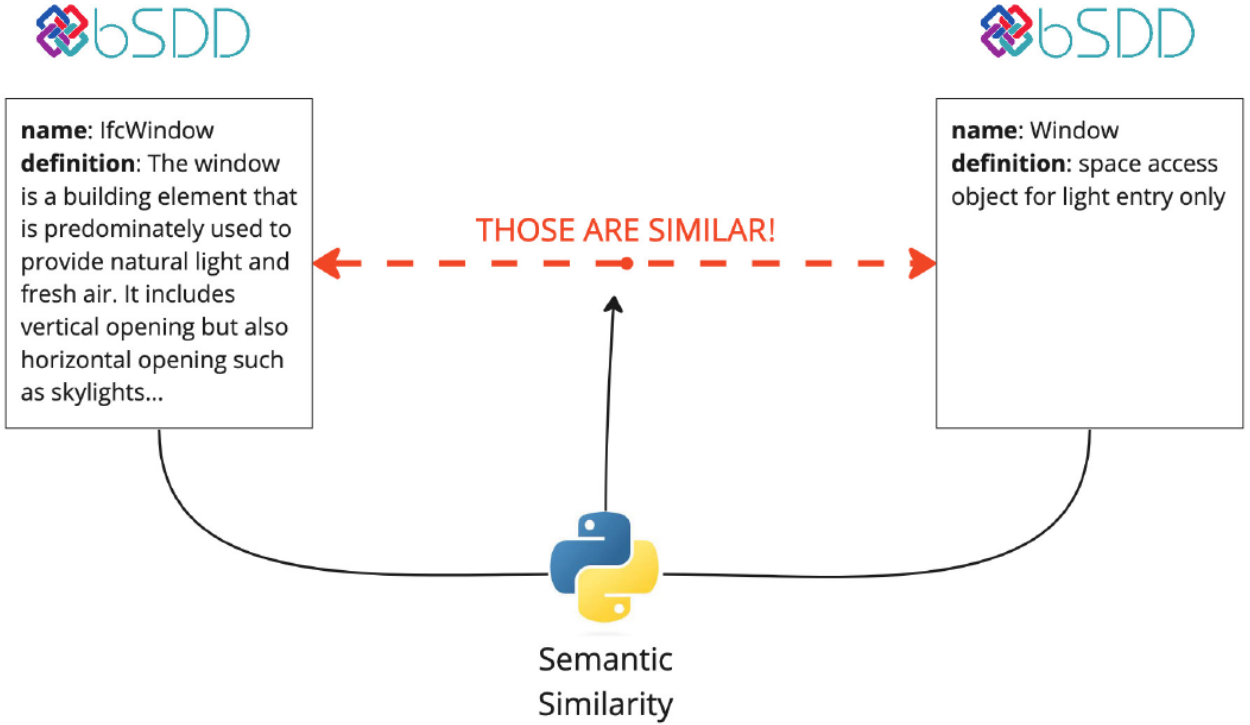
Natural Language Processing (NLP)



NLP Term Search



NLP Semantic Similarity



Before

Classification

IfcWall

English

Code

IfcWall

Classification type

Class

Namespace URI

https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/IfcWall

Description

The wall represents a vertical construction that may bound or subdivide spaces. Wall are usually vertical, or nearly vertical, planar elements, often designed to bear structural loads. A wall is however not required to be load bearing.{ .extDef}A wall may have openings, such as wall openings, openings used for windows or doors, or niches and recesses. They are defined by an IfcOpeningElement attached to the wall using the inverse relationship HasOpenings pointing to IfcRelVoidsElement. Walls with openings that have already been modeled within the enclosing geometry may use the relationship IfcRelConnectsElements to associate the wall with embedded elements such as doors and windows.There are two main representations for all occurrences:IfcWall

None

Classification relations

After

Classification

IfcWall

English

Code

IfcWall

Classification type

Class

Namespace URI

https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/IfcWall

Description

The wall represents a vertical construction that may bound or subdivide spaces. Wall are usually vertical, or nearly vertical, planar elements, often designed to bear structural loads. A wall is however not required to be load bearing.{ .extDef}A wall may have openings, such as wall openings, openings used for windows or doors, or niches and recesses. They are defined by an IfcOpeningElement attached to the wall using the inverse relationship HasOpenings pointing to IfcRelVoidsElement. Walls with openings that have already been modeled within the enclosing geometry may use the relationship IfcRelConnectsElements to associate the wall with embedded elements such as doors and windows.There are two main representations for all occurrences:IfcWall

Classification relations

URI	*Name*	*Relation type*
https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/IfcWindow	IfcWindow	HasReference
https://identifier.buildingsmart.org/uri/buildingsmart/ifc-4.3/class/IfcDoor	IfcDoor	HasReference
https://identifier.buildingsmart.org/uri/molio/cciconstruction-1.0/class/L-QQA	Wall	equivalentClass

Open Challenges

- How best to organize the data?
- How best to determine modularity?
- How to store each stakeholder's data requirements?
- How best to automate the classes and properties?
- How to be bi-directional from the diagrams (industry knowledge) to .owl?

Thank you

Aaron Costin, Ph.D.
aaron.costin@ufl.edu