Ontology Visualization Methods & Tools: A Survey of the State of the Art

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VOILA! 2018

ISWC 2018
MONTEREY, CA OCTOBER 8-12

Why?

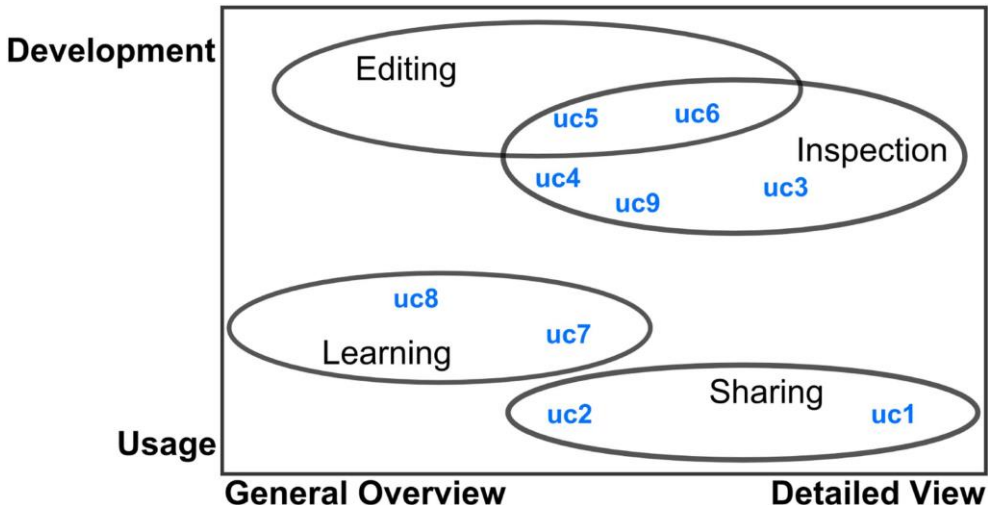
- Numerous visualization methods for ontologies
- Many software tools implementing them
- No one-size-fits-all solution
- No de facto standard
- Last comprehensive survey > 10 years old [Katifori et al. 2007]

→ Updated survey on methods and tools visualizing OWL ontologies

Methodology

- Keyword: “ontology visualization” (incl. variation with “s”)
- Sources: Google, Google Scholar, ACM DL + all VOILA Proceedings
- Analyzed: Paper contents + related work + references
- Target: OWL visualization methods and tools (incl. related work)
- Tested: Most recent tool version (where available)
- Platform: Tested with Windows 10 and Ubuntu 14 PCs

Categorizations

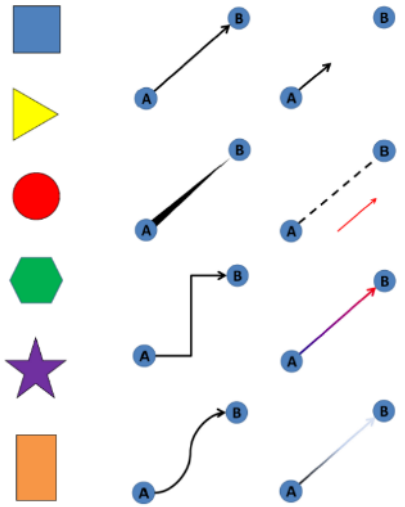


Methods:

1. Dimensions (2D, 3D, etc.)
2. Graphical Elements (glyphs)
3. Layout Method (tree, force, etc.)

Tools:

1. Interaction Techniques (zooming, searching, etc.)
2. OWL coverage (tested with OntoViBe)
3. Large ontologies (tested with SUMO)



[Burch & Lohmann 2015]

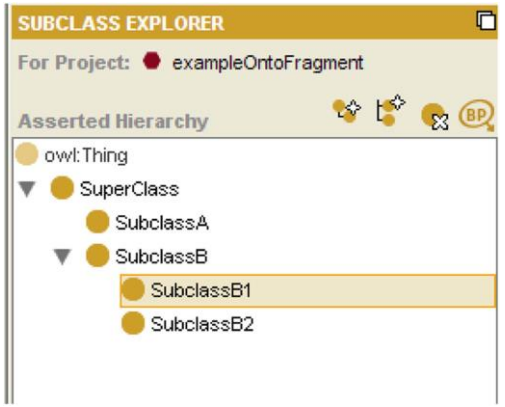
1.5D Visualization Method: Indented Lists

- Hierarchical relations (e.g. class hierarchy)
- One type of entity at a time (e.g. classes)
- Graphical elements: text labels (+symbols, line fragments)

Indented List

SuperClass
    SubClassB
        SubClassB1
        SubClassB2
    SubClassA

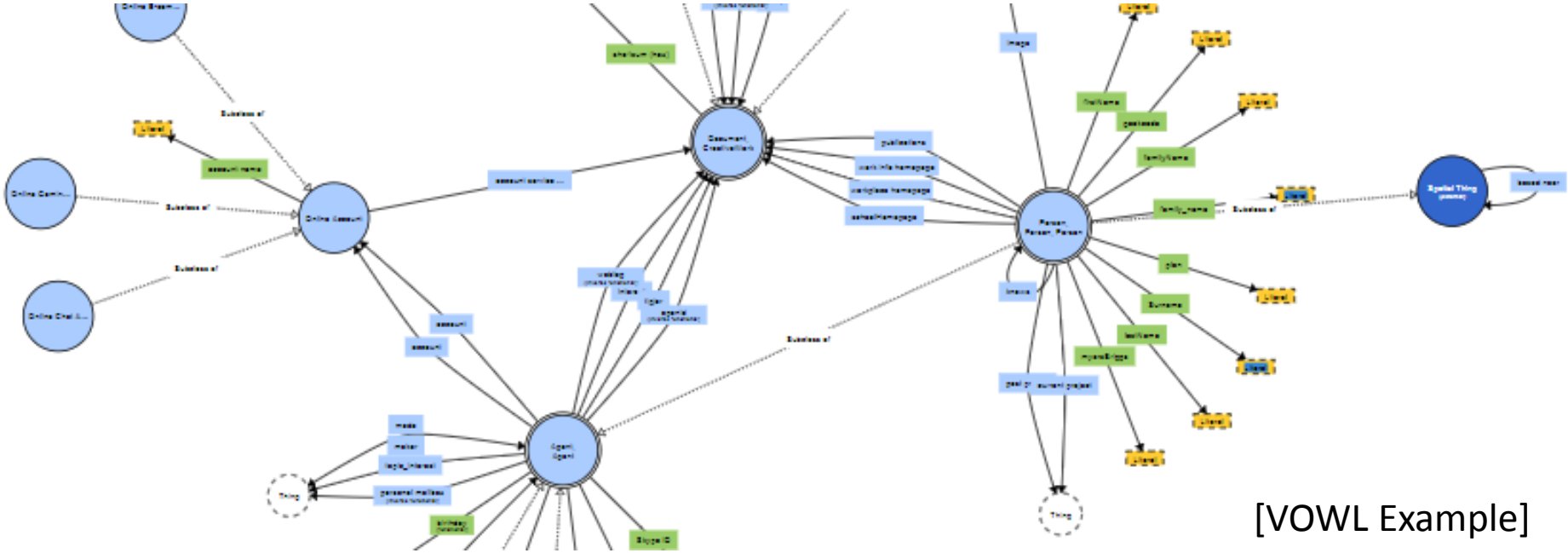
Pros	Cons
• Familiarity • Visual clarity • Ease of use • Easy to implement	• Only hierarchies • Only one entity type at a time • Often much scrolling • Multiple inheritance only via multiplication



[Entity Browser of Protégé]

2D Visualization Method: Node-link Diagrams

- Most frequently used ontology visualization method
- Labeled nodes are connected by (optionally labeled) links
- Nodes = entities (classes), links = relations between entities



[VOWL Example]

Node-link Diagrams vs. Indented Trees

Indented tree	Node-link diagrams
List-checking tasks	Overviews
Larger ontologies	Smaller ontologies
Hierarchically organized	Network structure
Few customization options	Many customization options
Single inheritance	Multiple inheritance

[Fu et al. 2013]

Node-link Diagrams vs. Indented Trees

Visualization	Conference Task	BioMed Task
Indented Tree		
Graph		

[Fu et al. 2013]

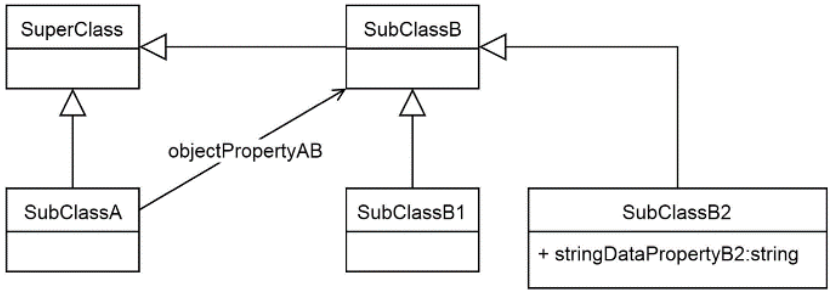
Categorization: Label-based vs. Layout-based

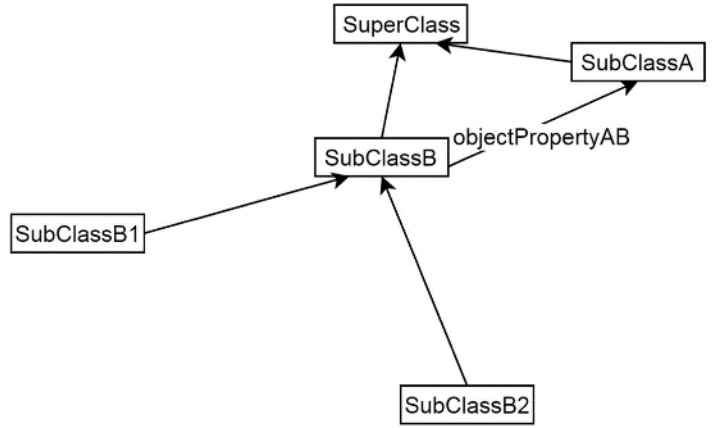
Label-based:

- UML-inspired: node label = name + other information (data properties)
- Name-label-only: node label = name & no other textual information

Layout-based:

- Force-directed
- Tree
- Radial
- Circle
- …



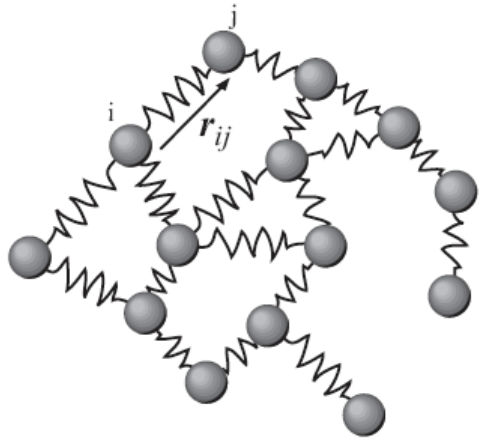


UML-inspired visualizations: Similarities between Ontology Engineering and Software Engineering

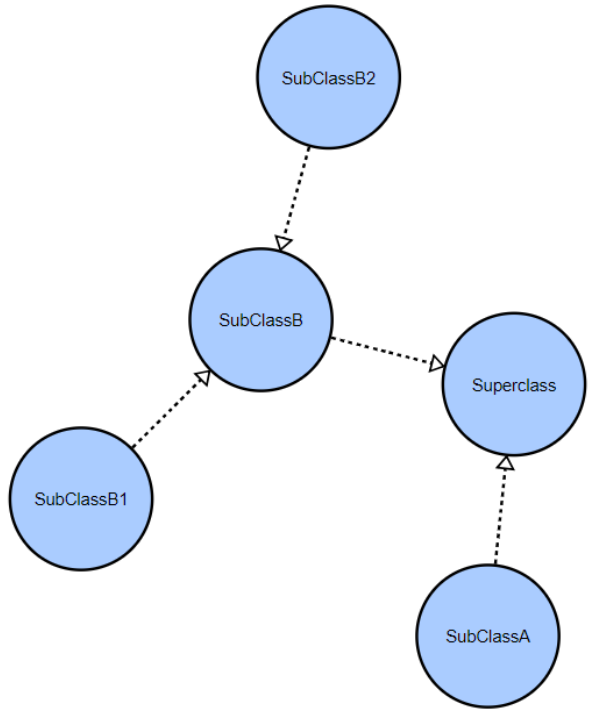
Force-directed Layout

- Also called “spring embedded” layout
- Very common in ontology visualization
- Algorithm simulates a physical system
- Nodes with most connections are arranged in the center

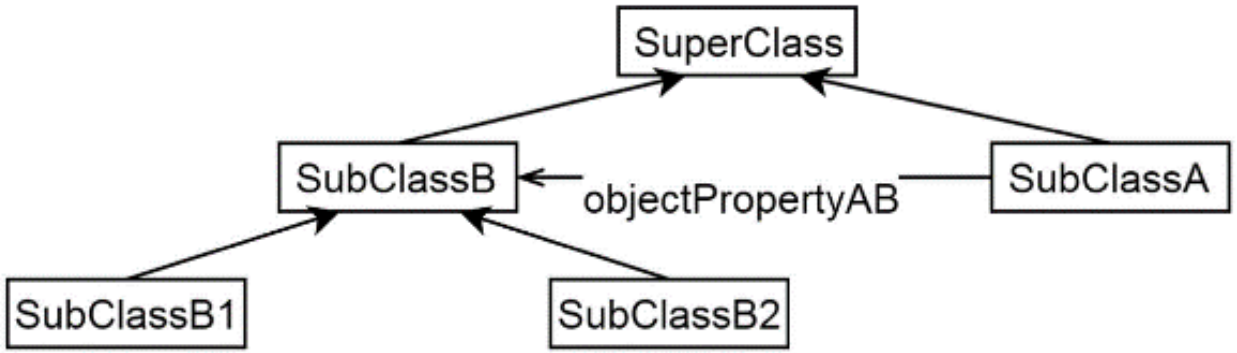
Pros	Cons
edge crossings & overlapping nodes are avoided	Instability of most force-directed layouts

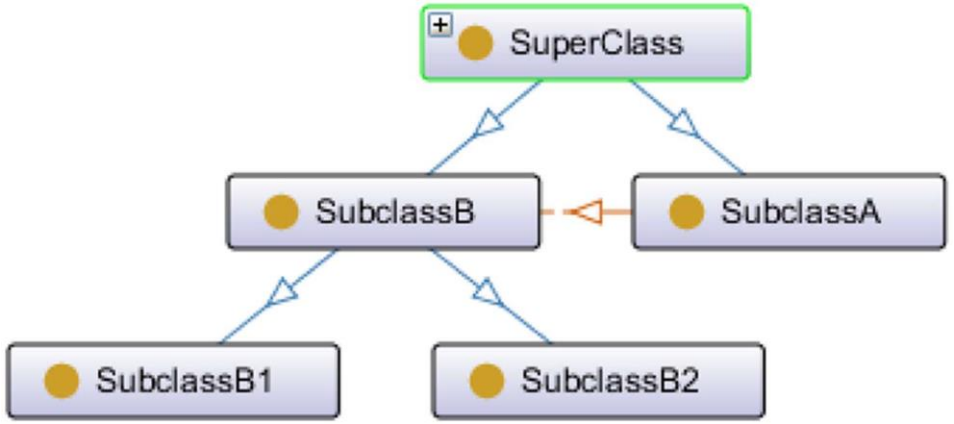


[Wikipedia]



Tree Layout

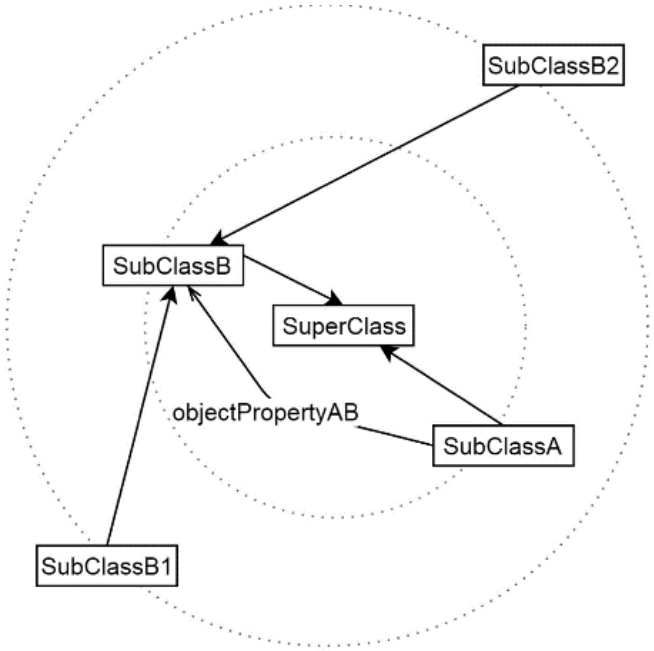


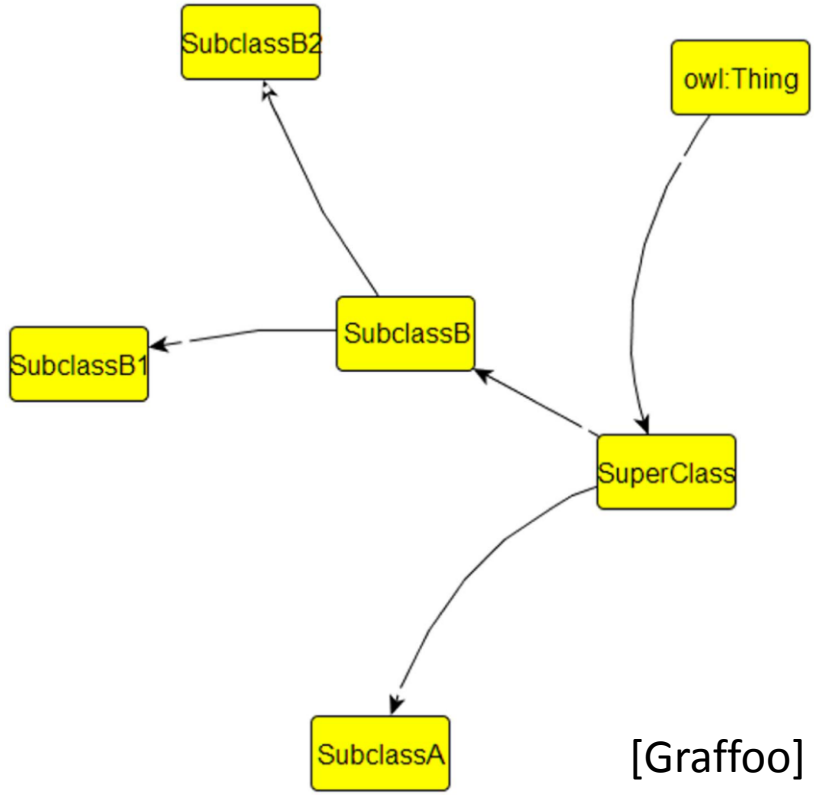


[OntoGraf plugin for Protégé]

Pros	Cons
Stable layout	Only hierarchical relations

Radial Layout

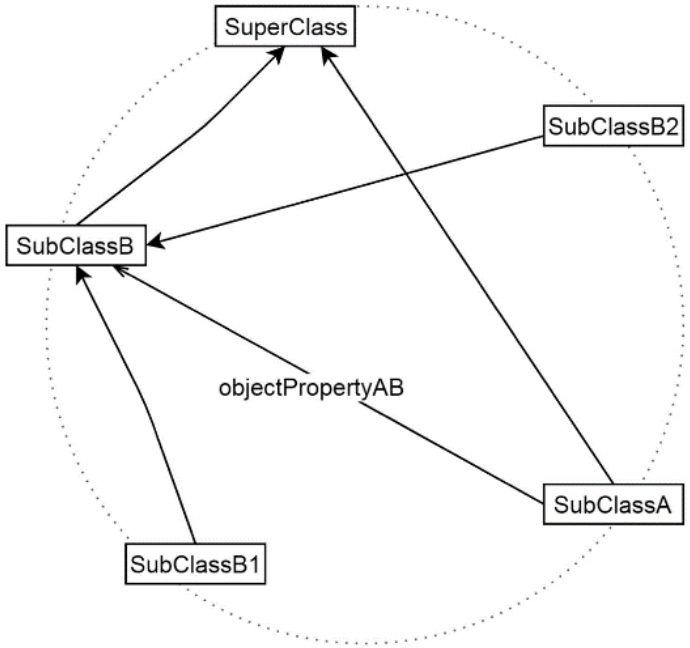


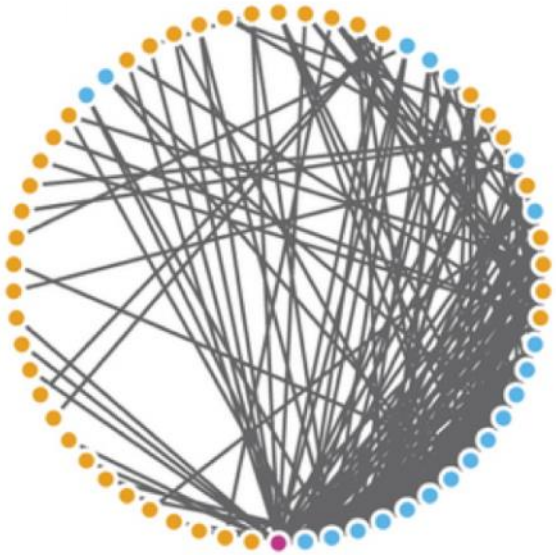


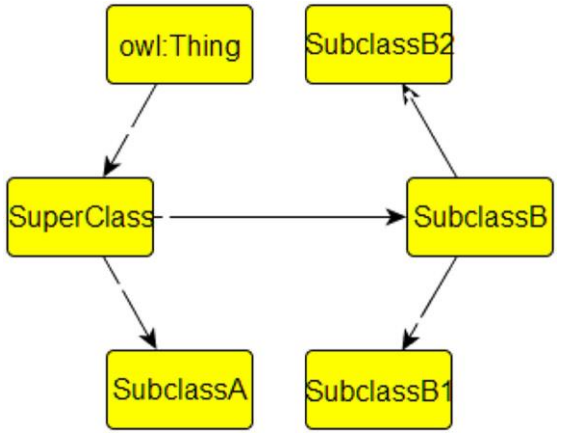
[Graffoo]

Pros	Cons
Can be more space efficient than tree layout	Hierarchical structure can be less noticable

Circle Layout



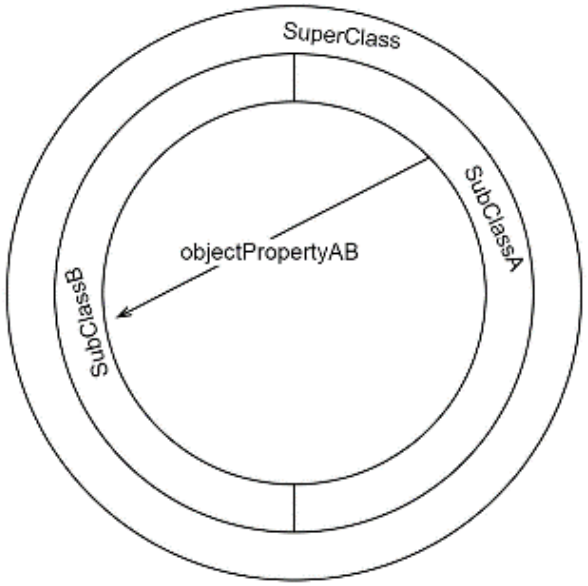


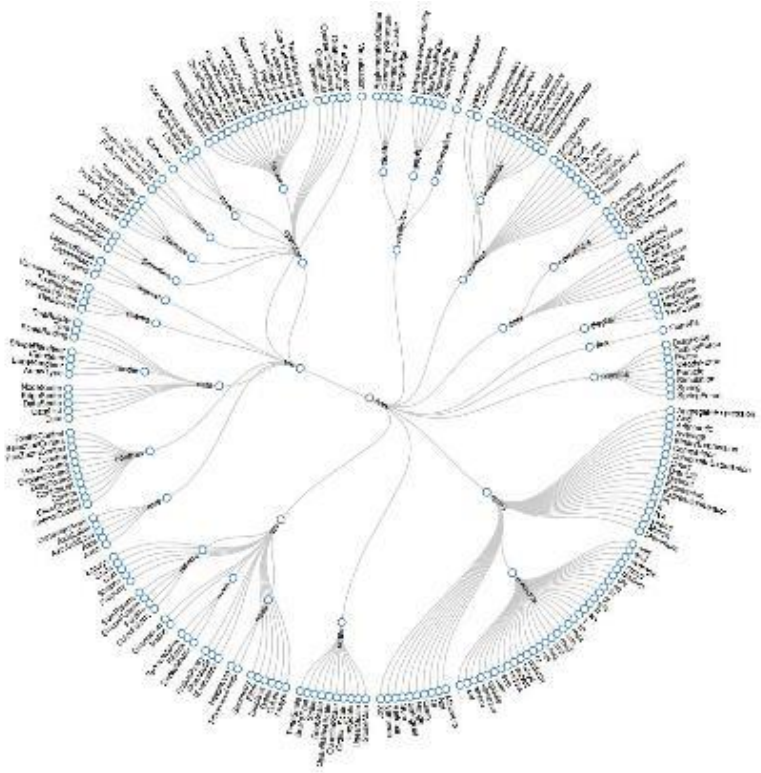


[Graffoo]

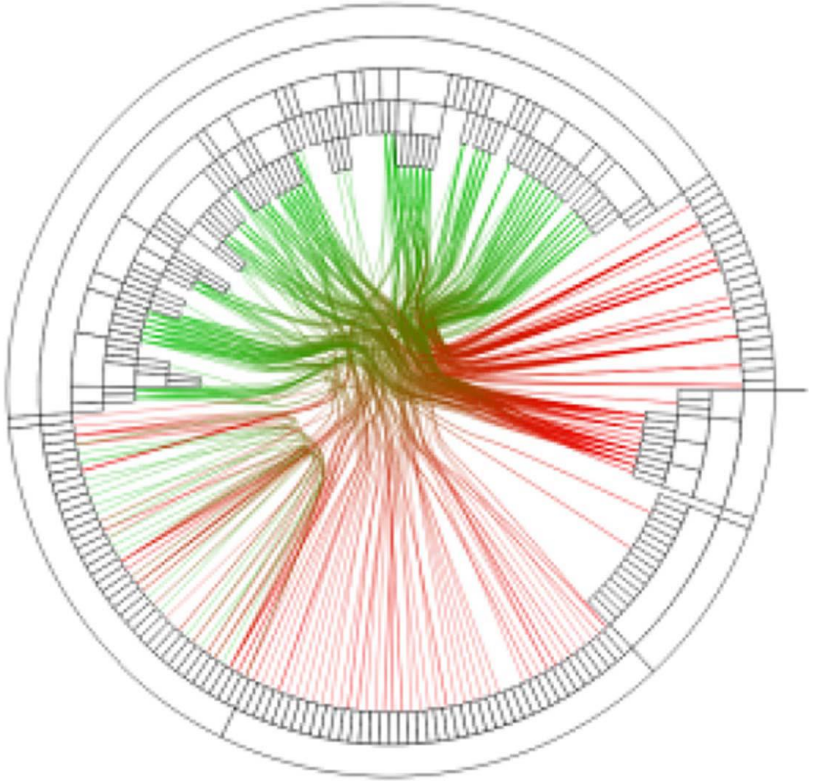
Pros	Cons
Can nicely be combined with edge bundling & sunburst diagrams → Inverted radial tree layout	• Space consuming • Long relation links • Rotated text

Inverted Radial Tree Layout





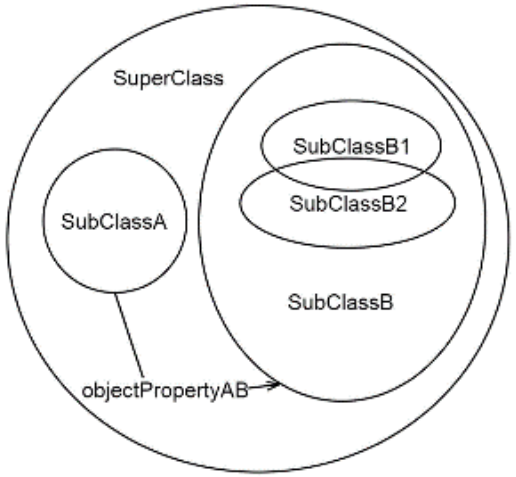
[bl.ocks.org]

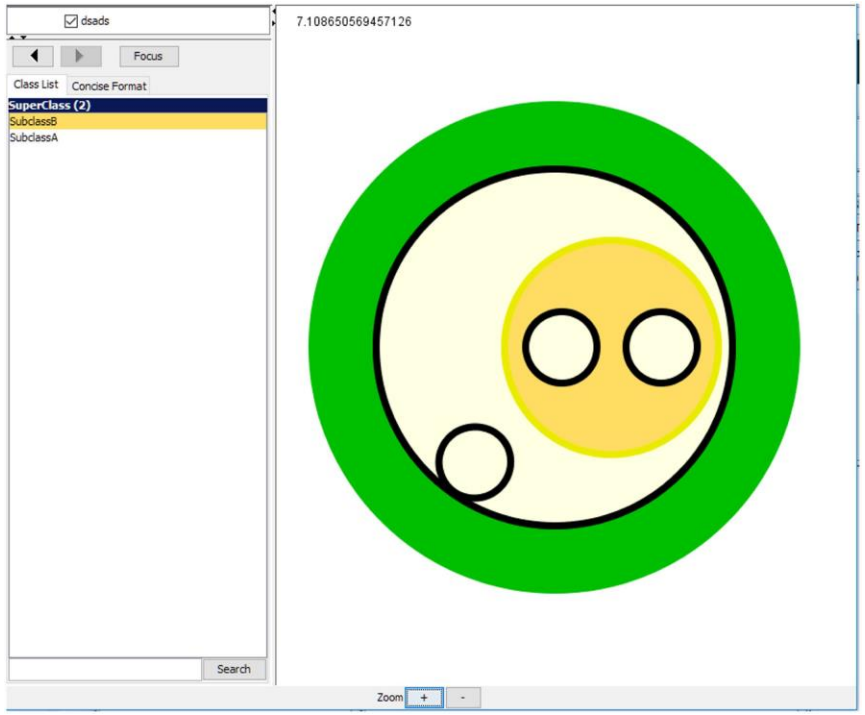


[GLOW plugin for Protégé]

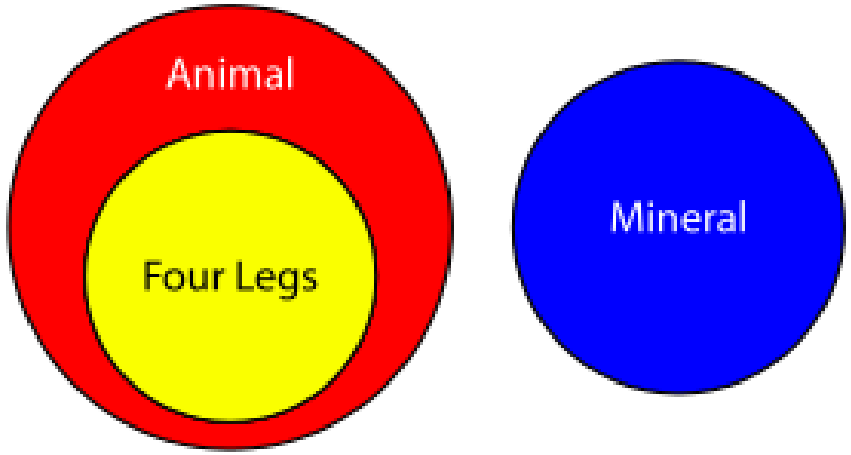
2D Visualization Methods: Euler Diagrams

- Hierarchical and other relations (e.g. distjointness)



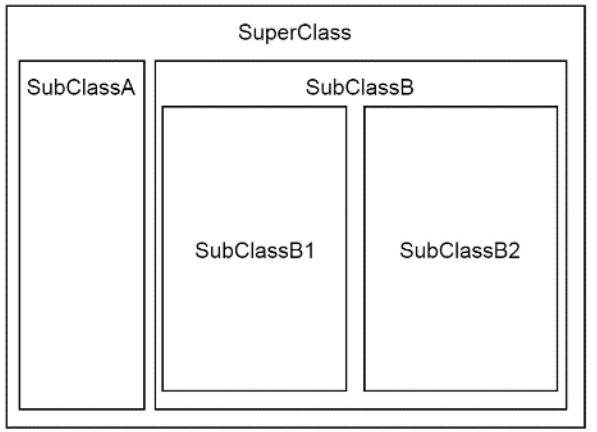


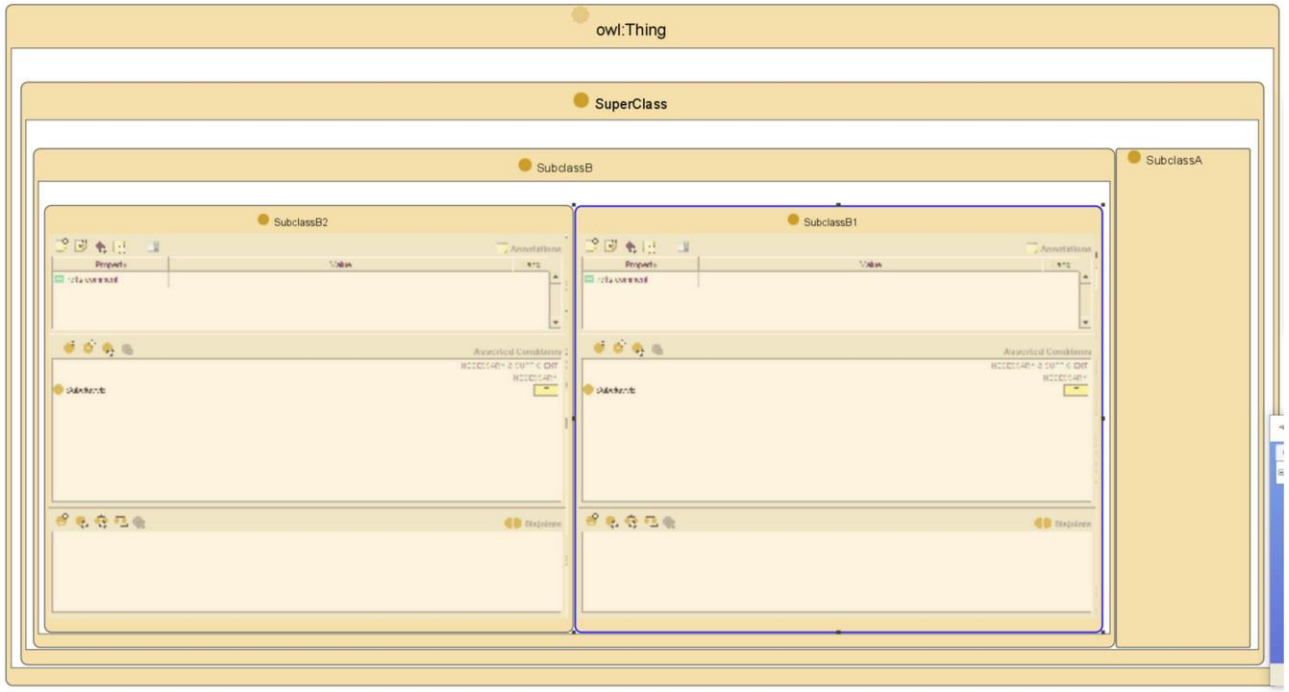
[SWOOP]



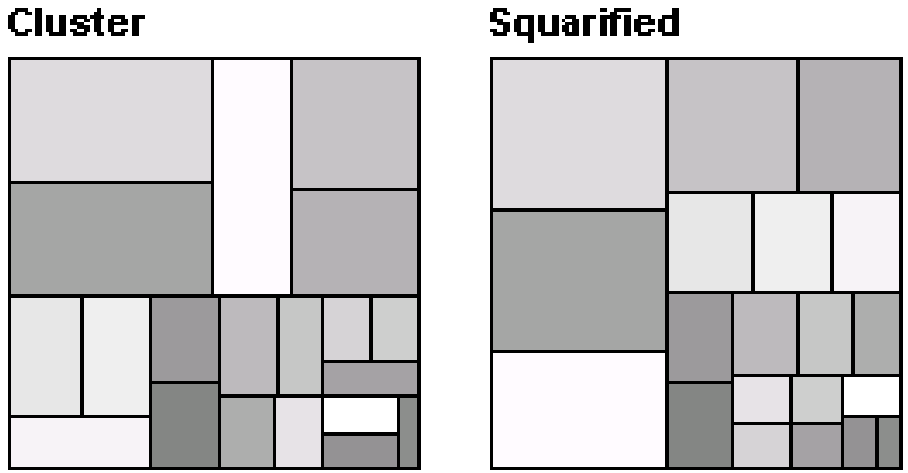
2D Visualization Methods: Treemaps

- Hierarchical relations





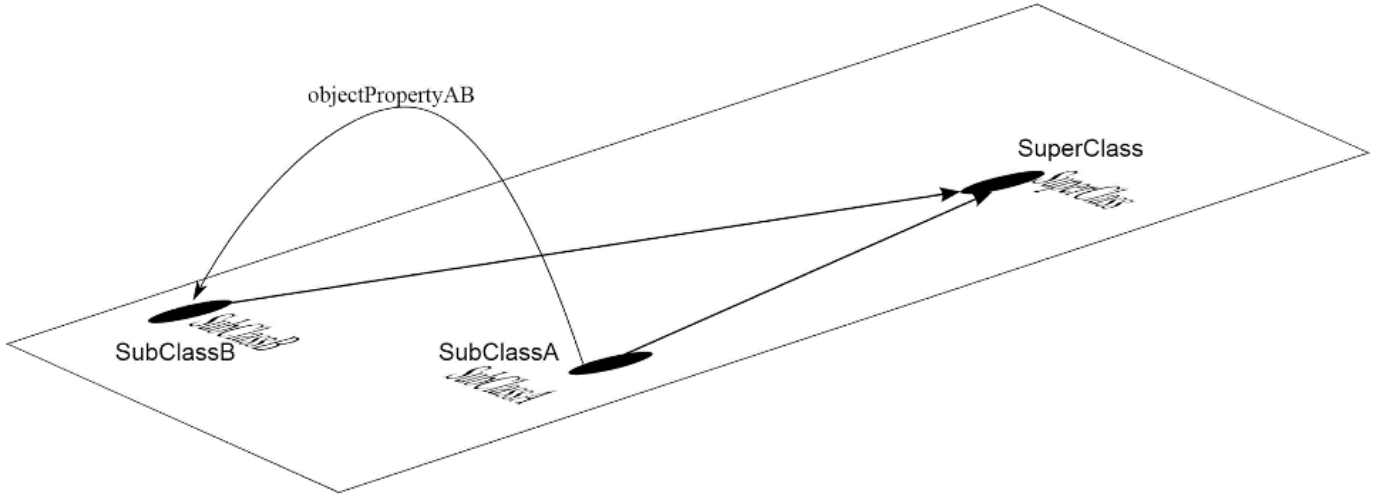
[Jambalaya]

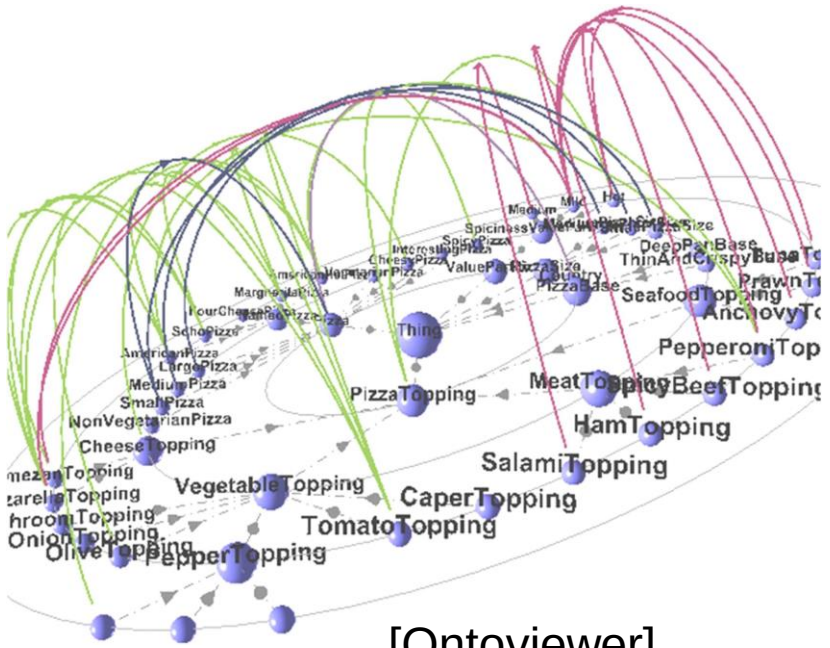


2.5 Visualization Methods

- Only one experimental tool (Ontoviewer)

[ThemeScape]

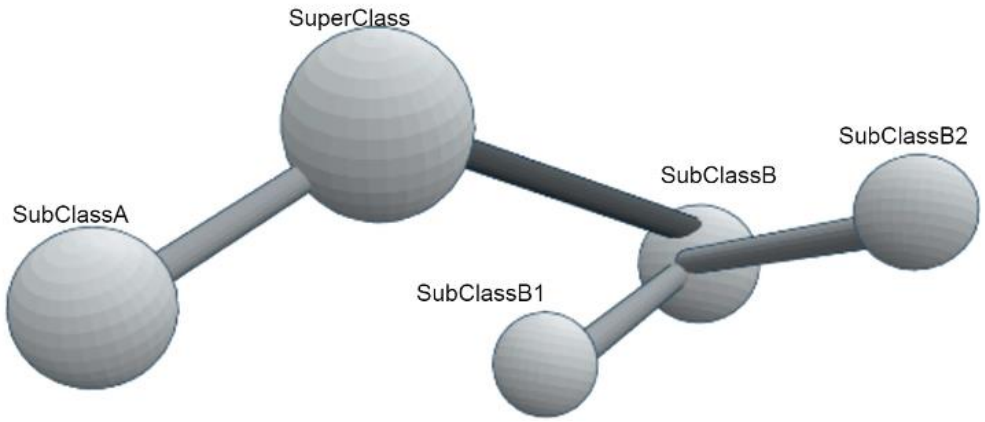


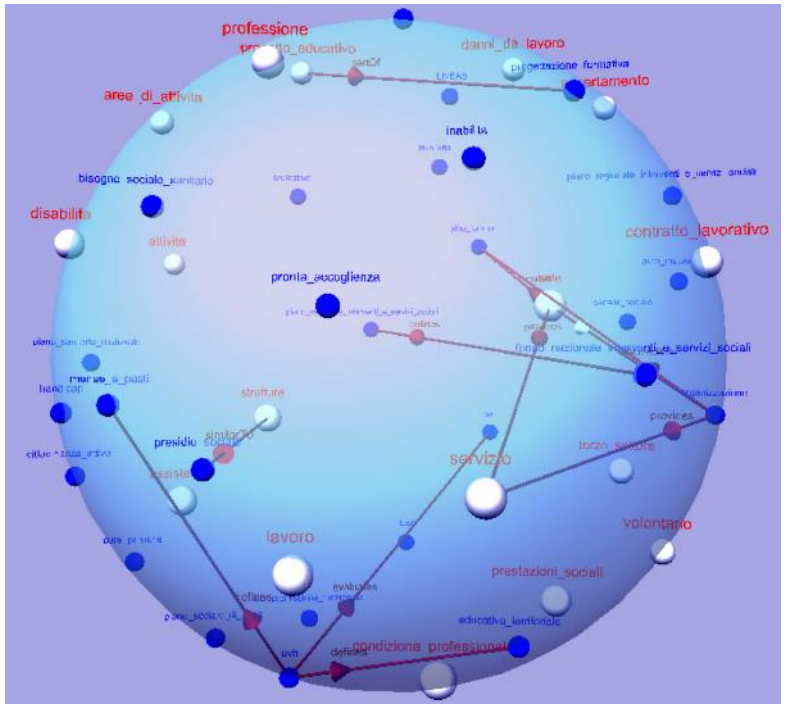


[Ontoviewer]

3D Visualization

- Only two experimental tools (OntoSphere and OntoSELF)



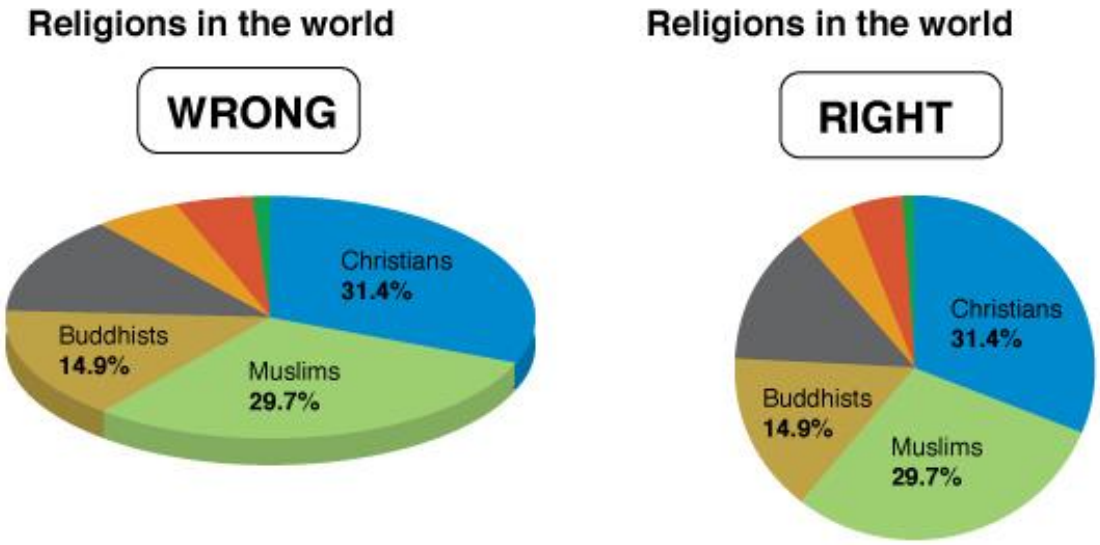


[OntoSphere]

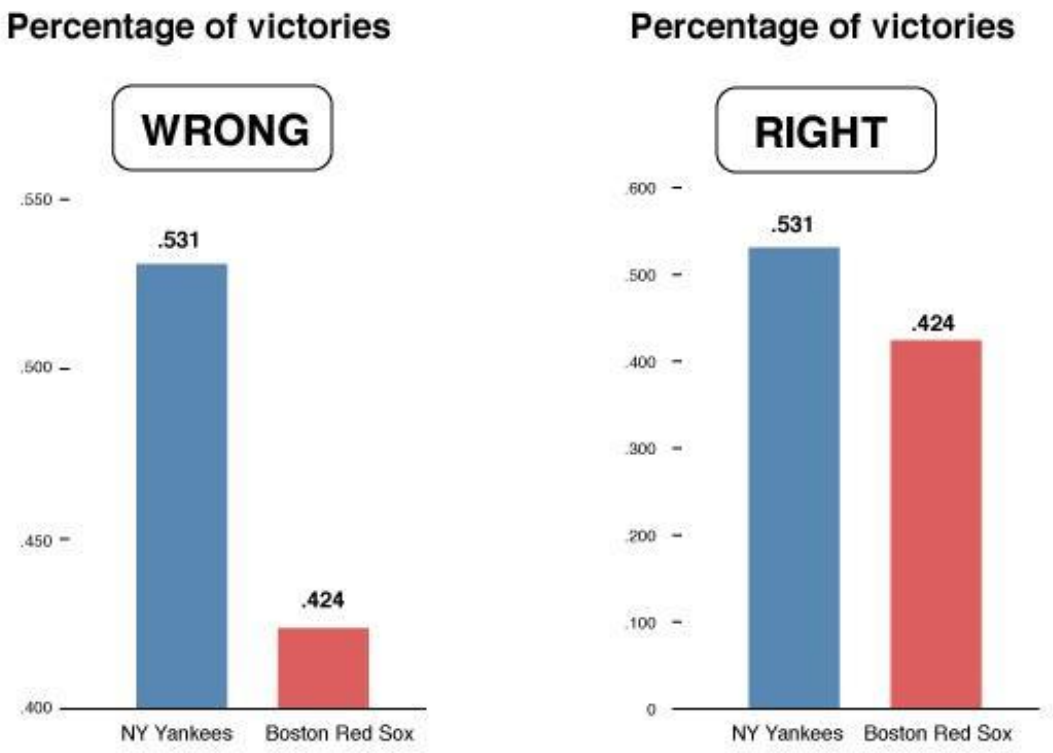
Pros	Cons
Explore from different angles	Screens are 2D (require transformation)

Brief Digression: Visual Lies

- Visual lies are a general issue
- More an issue in 3D than in 2D



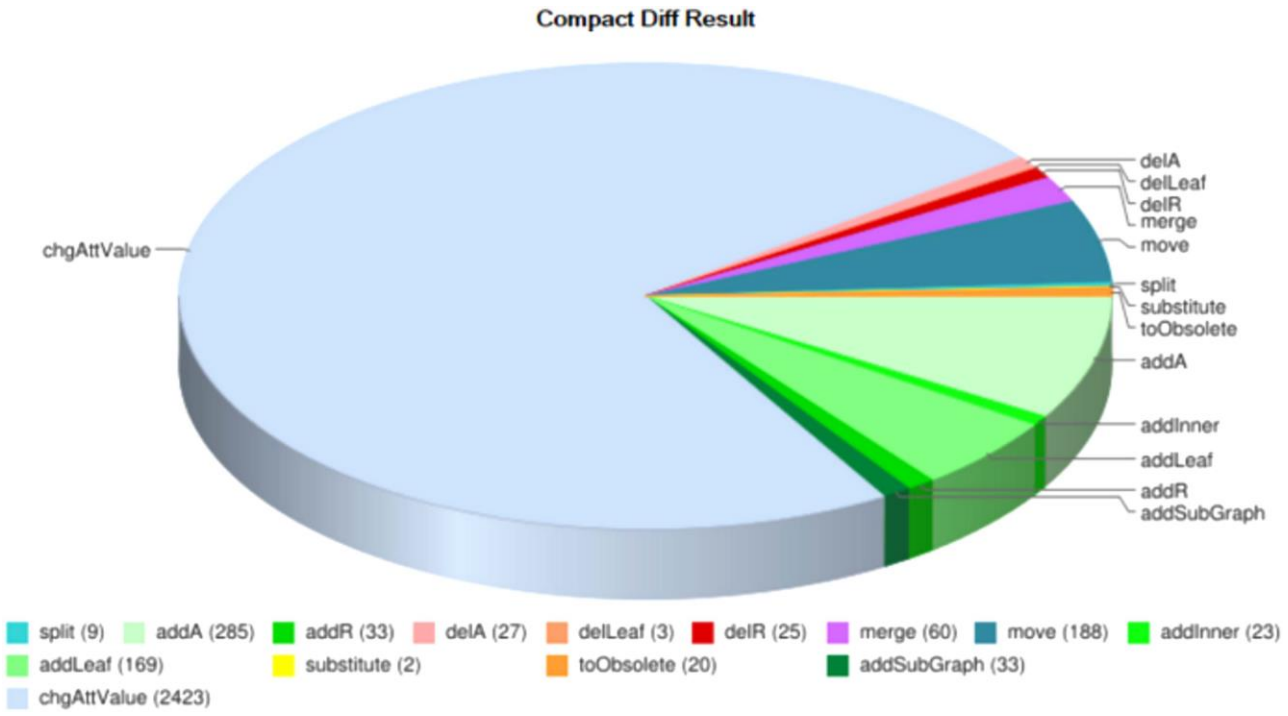
[Pew Research Center / National Geographic]



[Major League Baseball / National Geographic]

4D Visualization

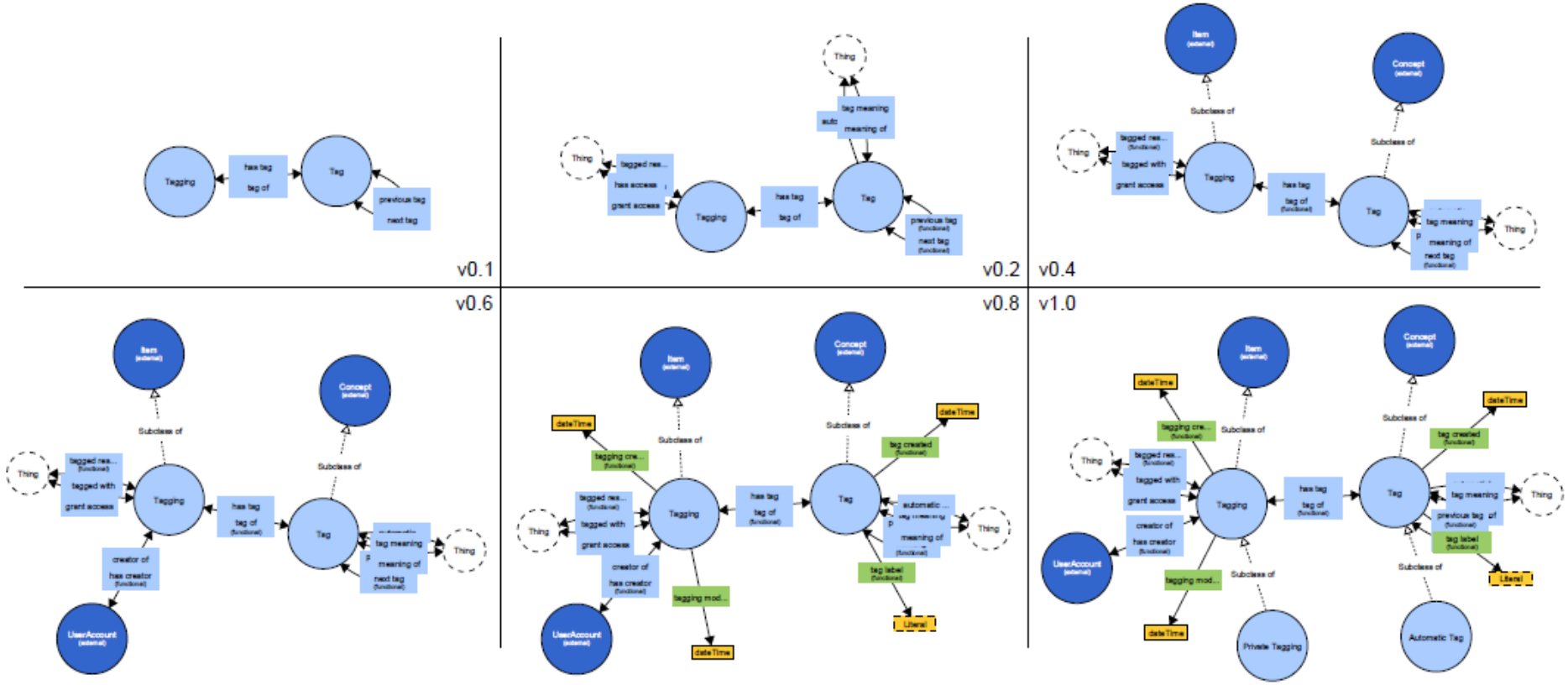
- Little explored
- Example: ontology evolution
- Use animation to depict the change of ontologies



[CODEX]

Ontology Evolution

- Time-to-time vs. time-to-space mappings



[Burch & Lohmann 2015]

Surveyed Tools

	Available	Works	Plugin for	Large ontologies: Loads	Large ontologies: Displays readable
CmapTools Ontology Editor	Yes	No		N/A	
CropCircles	Yes	Yes	SWOOP	No	
FlexViz	Yes	No		N/A	
GLOW	Yes	No	Protégé 4.x	N/A	
Graffoo	Yes	Yes		No	
GrOWL	No	No		N/A	
Jambalaya	Yes	Yes	Protégé 3.x	No	
KC-Viz	Yes	Yes	Neon Toolkit	No	
Knoocks	Yes	No		N/A	
Multi-view ontology visualization	No	No		N/A	
NavigOWL	Yes	Yes	Protégé 4.x	No	
OLSVis	Yes	Yes		N/A	
Ontodia	Yes	Yes		Yes	Yes
OntoGraf	Yes	Ye	Protégé 4.x	Yes	Yes
Ontology visualizer	Yes	No	Neon Toolkit	N/A	
OntoRama	No	No		N/A	
OntoSELF	No	No		N/A	
OntoSphere	Yes	No	Protégé 3.x	N/A	
OntoStudio	Yes	Yes		Yes	Yes
OntoTrack	No	No		N/A	
OntoTrix	No	No		N/A	
Ontoviewer	No	No		N/A	
OntoViz	Yes	No	Protégé 3.x	N/A	
OWL-VisMod	Yes	No		N/A	
OWLeasyViz	Yes	No		N/A	
OWLGrEd	Yes	Yes		No	
OWLViz	Yes	Yes	Protégé 4.x	No	
Protégé Entity Browser	Yes	Yes	Protégé 4.x	Yes	Yes
SOVA	Yes	Yes	Protégé 4.x	No	
TGViz	Yes	Yes	Protégé 3.x	Yes	No
TopBraid	Yes	Yes		Yes	No
Triple20	No	No		N/A	
WebVOWL	Yes	Yes		No	

OWL Coverage

	Classes	Object properties	Datatype properties	Instances	Annotations	Universal/existential restrictions	Cardinality	Enumeration	Intersection	Union	Complement	Equivalent classes	Disjointness	Subclass relations	Property characteristics
CmapTools Ontology Editor	x	x	x	x										x	
CropCircles	x													x	
FlexViz	x	x												x	
GLOW	x	x												x	
Graffoo	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
GrOWL	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Jambalaya	x	x				x						x		x	
KC-Viz	x	x							x					x	
Knoocks	x	x	x	x										x	
Multi-view ontology visualization	x													x	
NavigOWL	x	x	x	x		x	x	x	x	x	x			x	x
OLSVis	x	x		x										x	
Ontodia	x	x	x	x	x	x						x	x	x	
OntoGraf	x	x		x		x		x	x	x	x	x		x	
Ontology visualizer	x													x	
OntoRama	x													x	
OntoSELF	x													x	
OntoSphere	x	x		x		x			x	x				x	
OntoStudio	x	x	x	x	x	x	x							x	x
OntoTrack	x	x	x									x	x	x	
OntoTrix	x	x		x											
Ontoviewer	x	x												x	
OntoViz	x	x	x	x		x	x	x	x	x	x	x		x	
OWL-VisMod	x	x	x					x	x	x		x	x	x	x
OWLeasyViz	x	x		x										x	
OWLGrEd	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
OWLViz	x													x	
Protégé Entity Browser	x	x	x	x										x	
SOVA	x	x		x		x	x	x	x	x	x	x	x	x	x
TGViz	x	x												x	
TopBraid	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Trip20	x	x	x	x	x		x	x	x	x	x	N/A	N/A	x	x
WebVOWL	x	x	x		x	x	x		x	x	x	x	x	x	x

Interaction Techniques

	Radar view	Graphical zoom	Entity focus	History (undo/redo)	Pop-up window	Incremental exploration	Search and highlight	Filter parts	Filter entity types	Fisheye distortion	Edge bundling	3D navigation	Panning	Drag and drop	Clustering	Textual editing	Visual editing
CmapTools Ontology Editor		x											x	x		x	x
CropCircles		x															
FlexViz		x					x		x				x	x			
GLOW																	
Graffoo	x	x	x				x						x	x			
GrOWL		x	x				x		x					x		x	x
Jambalaya		x	x		x	x	x	x	x	x				x		x	
KC-Viz		x		x	x	x		x	x				x	x	x	x	
Knoocks		x			x		x				x						
Multi-view ontology visualization							x			x							
NavigOWL	x	x			x		x						x	x			
OLSVis		x	x			x	x						x				
Ontodia		x	x	x	x	x	x	x	x				x	x		x	
OntoGraf		x	x		x	x	x		x				x	x		x	
Ontology visualizer		x	x	x		x	x							x			
OntoRama							x		x	x							
OntoSELF		x							x			x					
OntoSphere			x			x						x	x				
OntoStudio		x	x	x	x	x	x	x	x								
OntoTrack	x	x	x			x	x						x	x		x	x
OntoTrix	x	x	x				x		x		x		x	x	x		
Ontoviewer	x	x					x		x	x			x				
OntoViz		x						x					x				
OWL-VisMod																	
OWLeasyViz		x				x	x		x								
OWLGrEd	x	x		x	x						x			x		x	x
OWLViz		x				x		x								x	
Protégé Entity Browser					x	x	x									x	
SOVA		x					x		x				x	x			
TGViz		x	x			x	x	x	x	x			x				
TopBraid	x	x						x	x				x	x		x	
Triple20			x	x	x		x	x	x							x	x
WebVOWL		x			x		x		x				x	x			

Retinal Properties

	Color	Shape	Size	Saturation	Texture
CmapTools Ontology Editor					
CropCircles					
FlexViz	x	x			
GLOW	x				
Graffoo	x	x			
GrOWL	x	x		x	
Jambalaya	x				
KC-Viz					
Knoocks					
Multi-view ontology visualization	x		x		
NavigOWL	x		x		
OLSVis					
Ontodia	x	x			
OntoGraf	x				
Ontology visualizer					
OntoRama	x	x			
OntoSELF					
OntoSphere					
Ontodia	x	x			
OntoTrack					
OntoTrix	x				
Ontoviewer	x		x		
OntoViz					
OWL-VisMod					
OWLeasyViz	x	x			
OWLGrEd	x				x
OWLViz	x				
Protégé Entity Browser	x	x			
SOVA	x	x			x
TGViz					
TopBraid	x				
Triple20					
WebVOWL	x	x	x		

Findings

- Mostly 2D
- Mostly node-link
- Focus on class hierarchy
- Visual indicators (color, size, shape, etc.) little used
- Little support of OWL 2
- Large ontologies can often not be parsed and visualized (clutter)
- Limited maturity and usability

Findings

- Tools are often experimental research prototypes
- Little time and resources for full implementation in research
- That affects:
  - OWL coverage: only 2 tools implement all tested OWL concepts (OWLGrEd and TopBraid)
  - Performance: only 5 tools load large ontologies (Ontodia, OntoGraf, Entity Browser, TGViz and TopBraid)
  - Feature richness – only few feature-rich tools (KC-Viz, Jambalaya, Ontodia & WebVOWL)

Findings

- Promising visualization methods not used (e.g. parallel coordinates)
- Few evaluations about the effectiveness and efficiency of the methods
- Little work on visualizing ontology evolution and change
- Offering complementing visualization (multiple coordinated views)
- Different tasks and use cases demand different visualization methods
- New ontology visualization methods and tools are often developed from scratch

→ High demand for a universal and customizable ontology visualization framework

Questions?