



Knowledge Evolution and its Impact on Artificial Intelligence

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University of
Zurich ^{UZH}



Dynamic and Distributed
Information Systems



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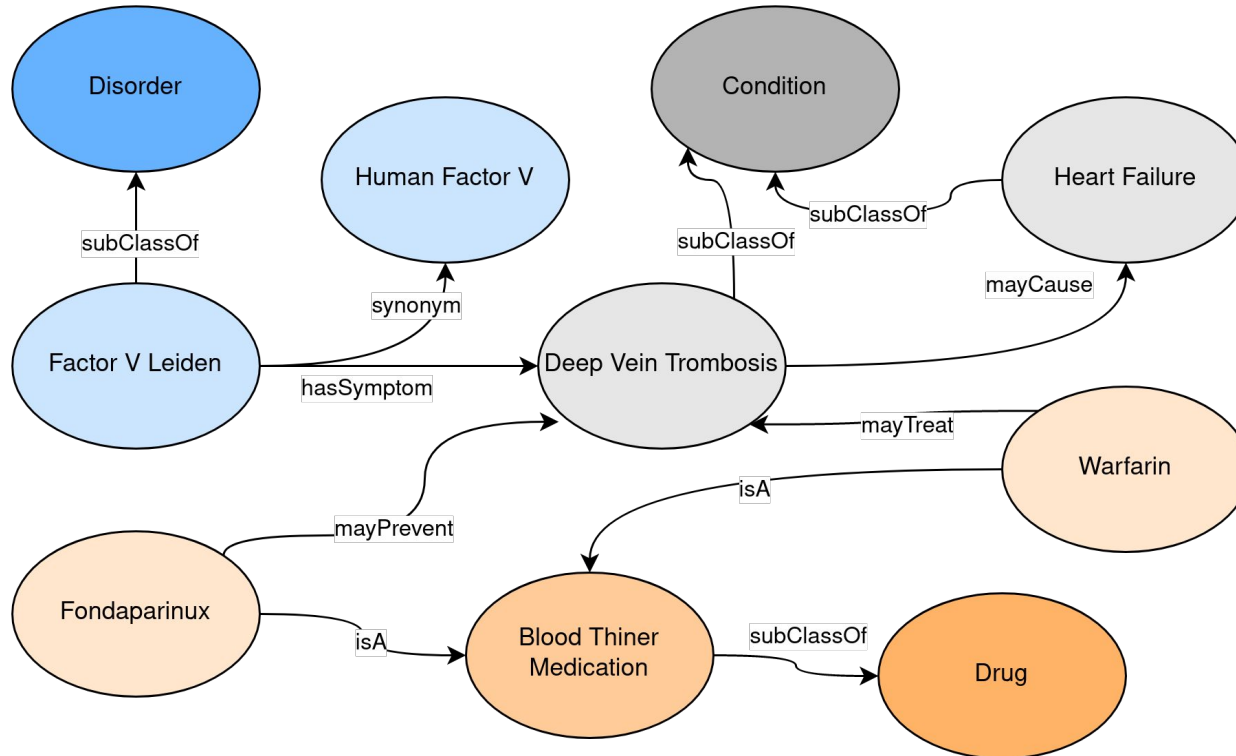


Knowledge in
Artificial Intelligence

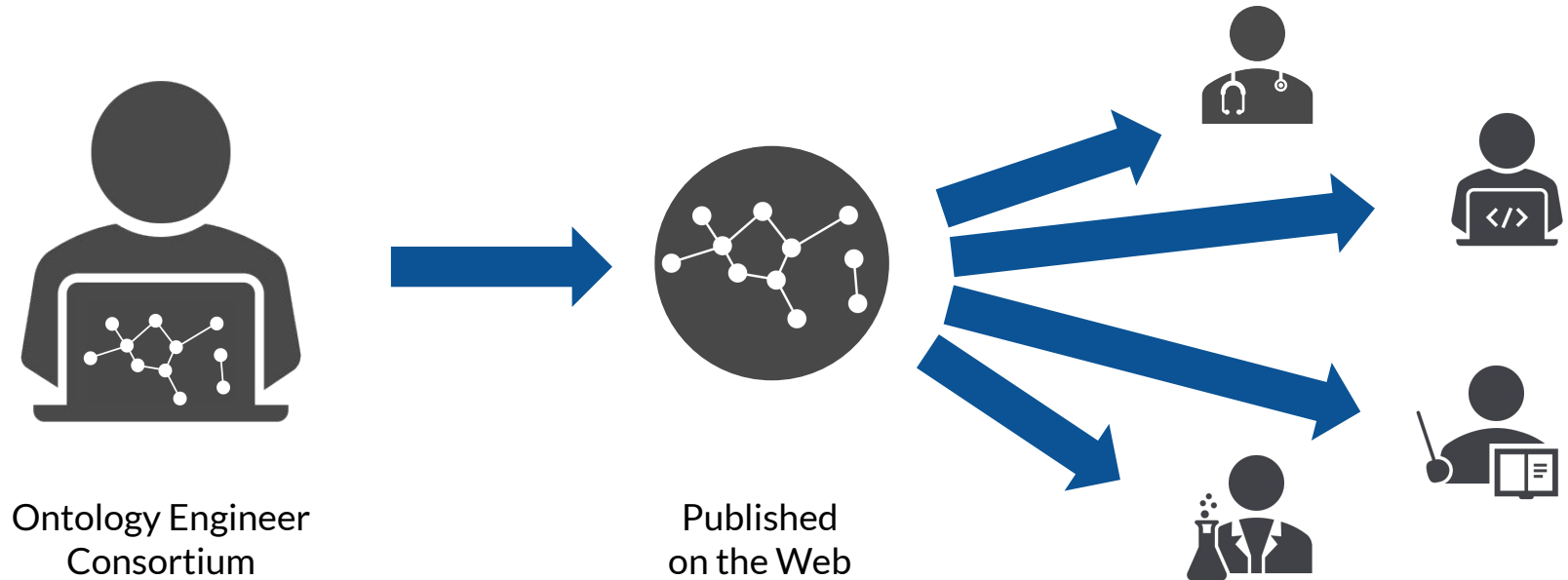


The Knowledge Evolution Problem

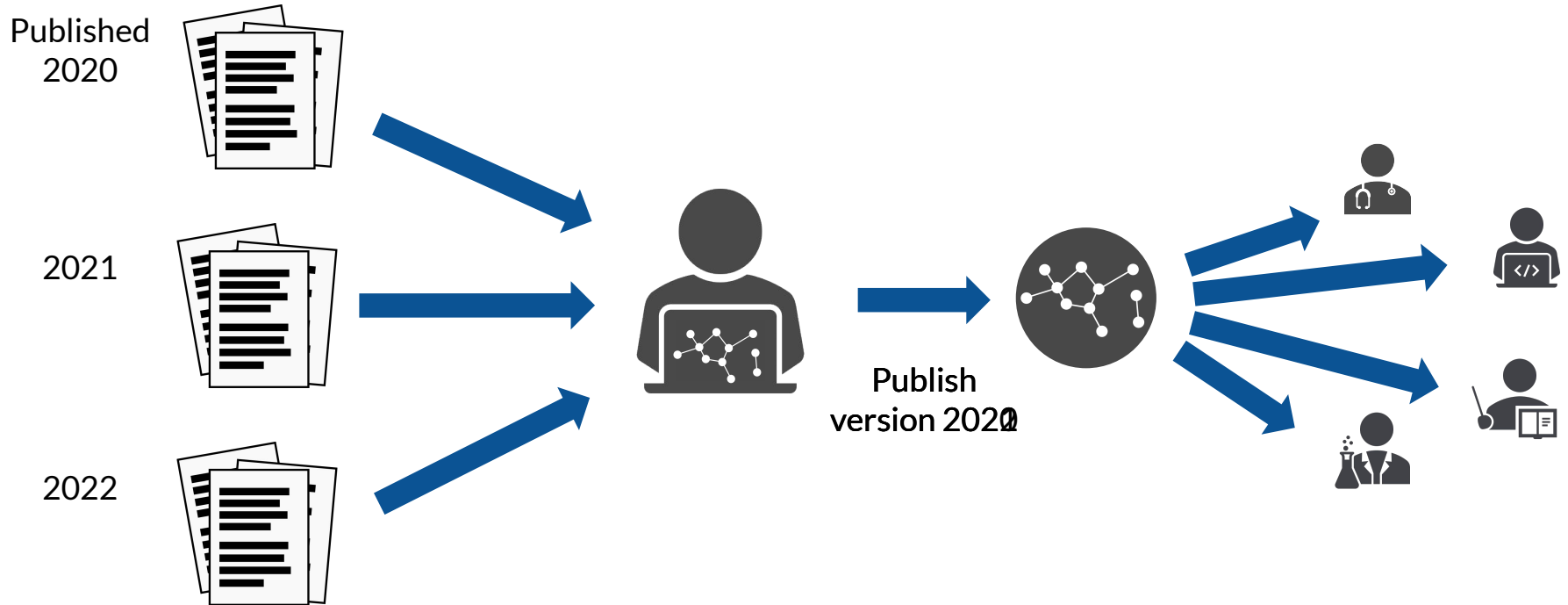
Ontologies and KGs model domain knowledge.



Ontologies are used in many applications.

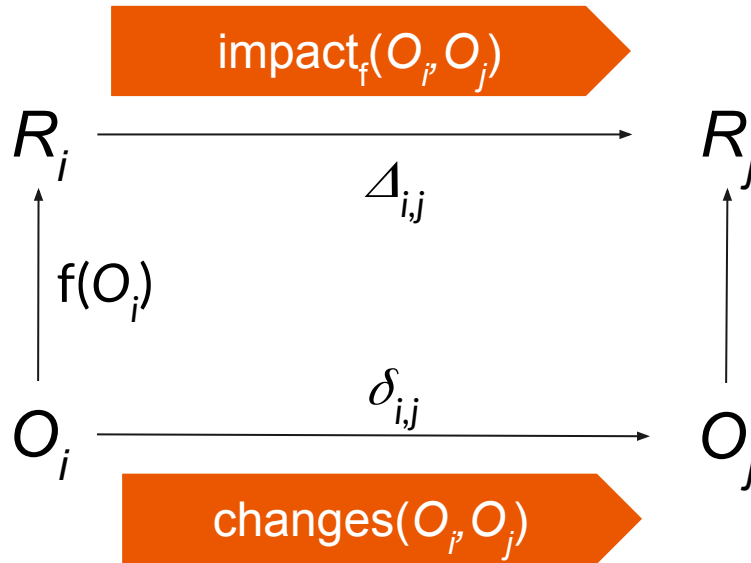
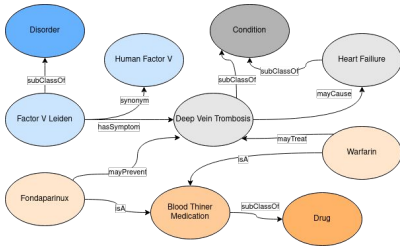


Knowledge evolves, applications need to update.

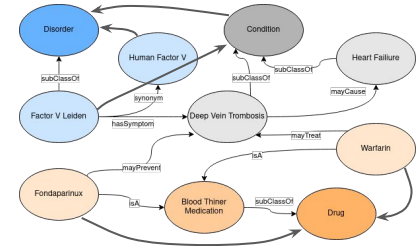


As ontologies evolve, results change too.

Treatment recommendation:
Warfarin



Treatment recommendation:
Warfarin or
Fondaparinux





The Knowledge Evolution Problem



Quantification

How can we capture the impact on the materialisation?

Analysis

Analysis of OBO ontology evolution and impact on materialisation.

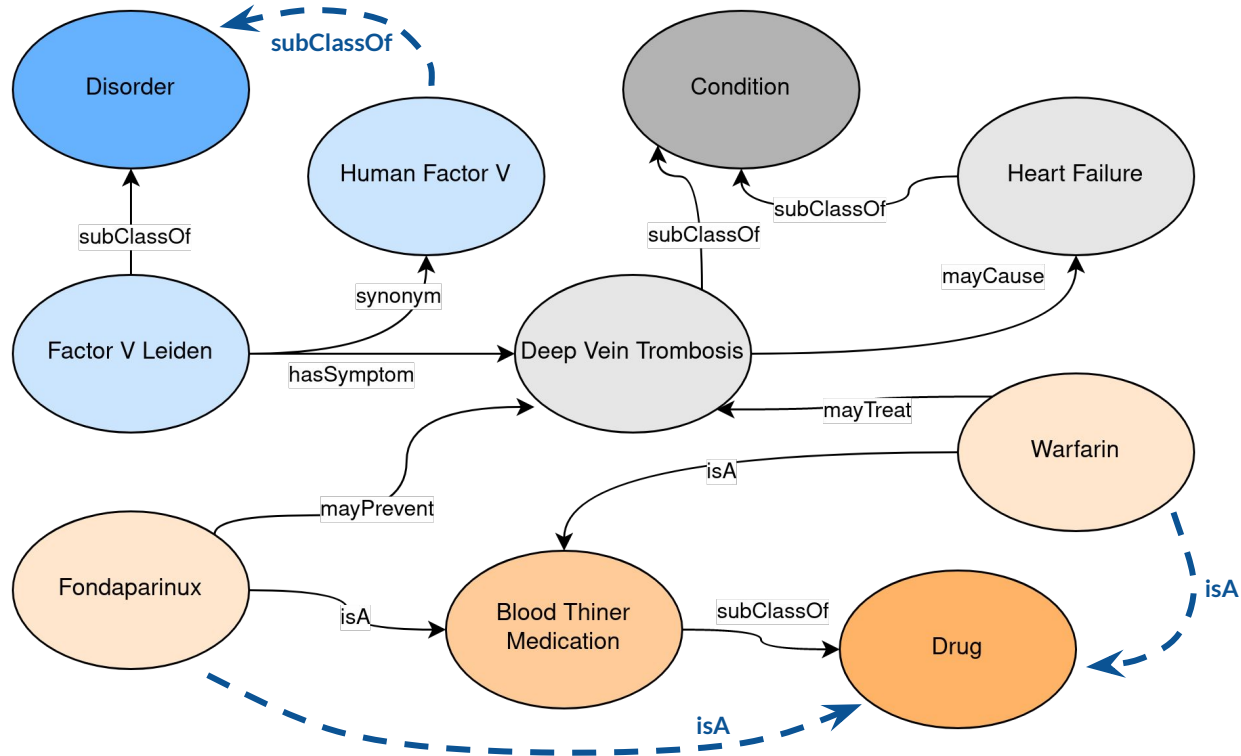
Management

How do ontology engineers understand the impact of ontology changes?

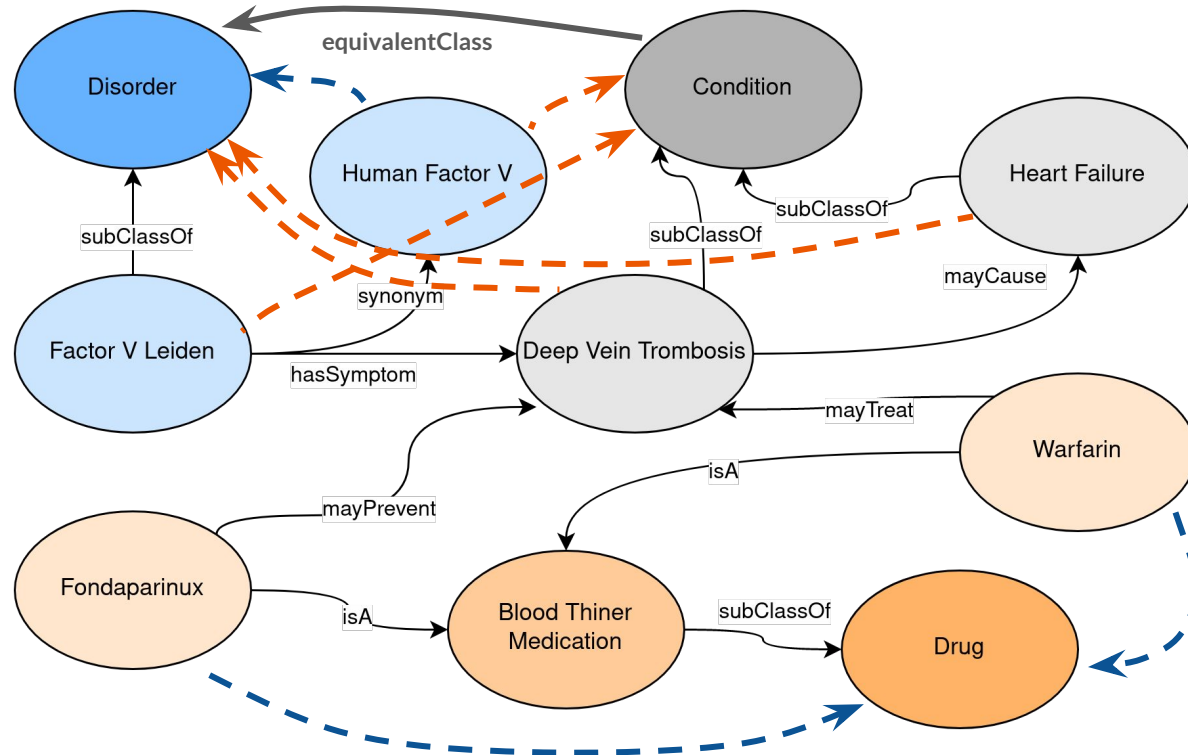
Quantification:

How can we capture the impact of ontology changes on the materialisation?

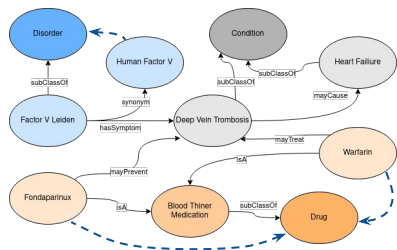
What is materialisation?



Changes can have catastrophic consequences.



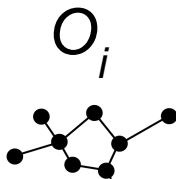
As ontologies evolve, results of change too.



impact_{mat}(O_i, O_j)

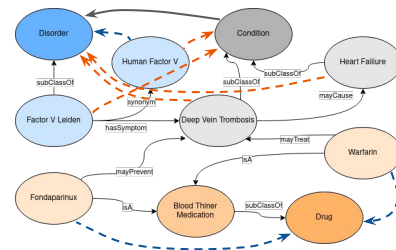
M_i

mat(O_i)



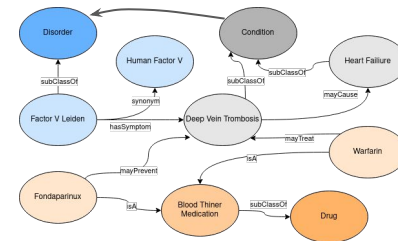
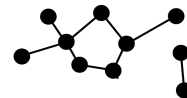
$\Delta_{i,j}$

M_j

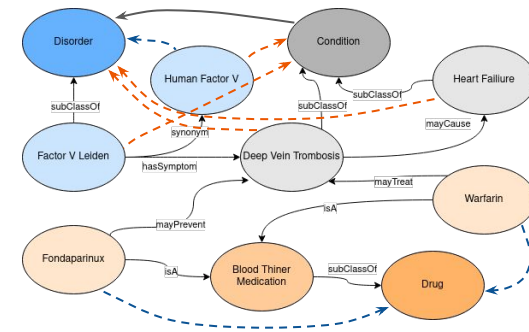
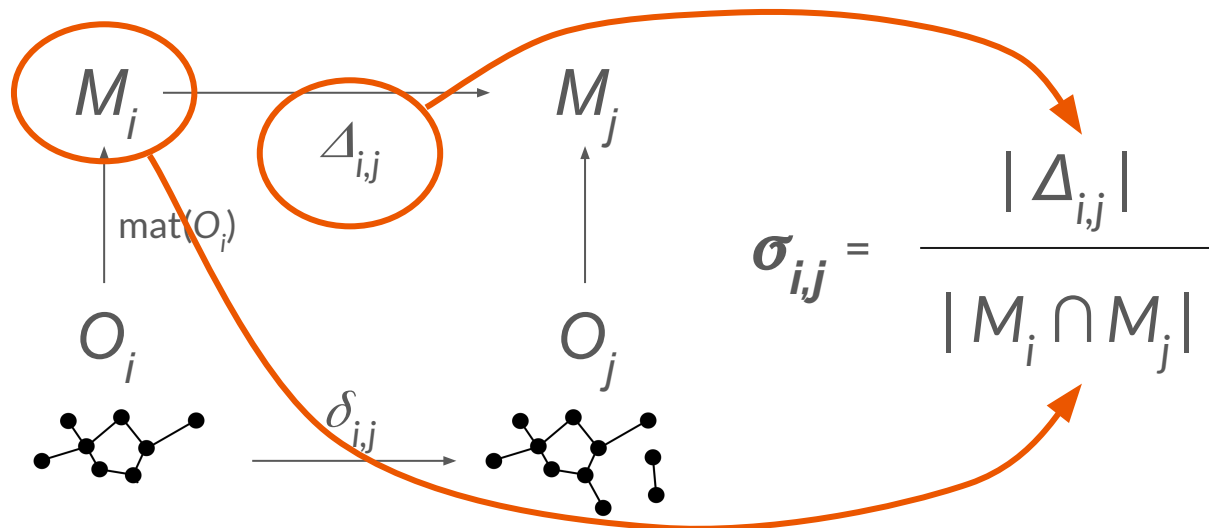


O_j

$\delta_{i,j}$

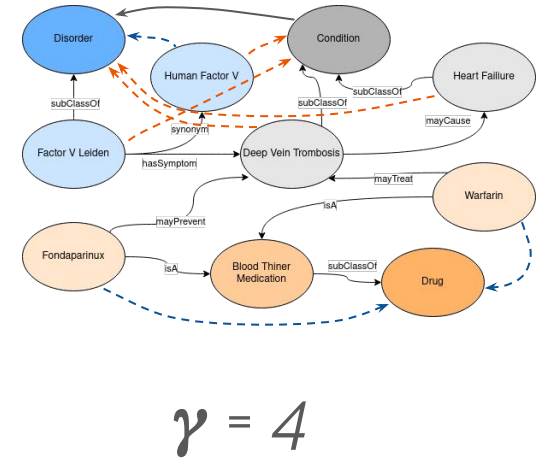
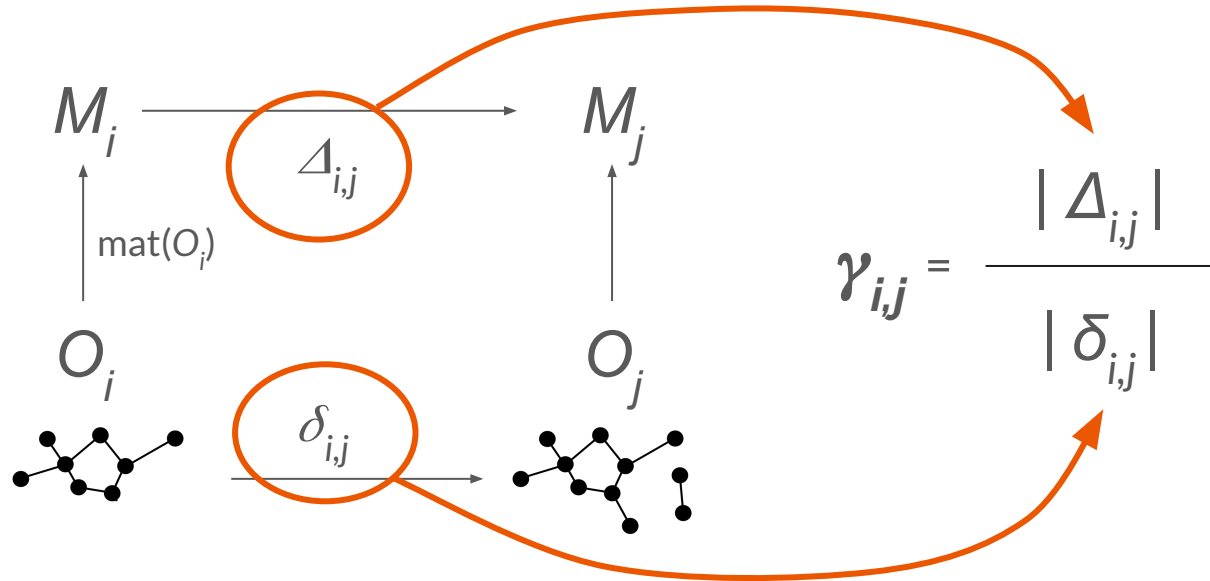


Size-based Impact σ_{ij}



$$\sigma = 1.33$$

Change-based Impact γ_{ij}



**We defined materialisation
impact measures at
macroscopic scale.**



Materialisation



How can we capture the impact on the materialisation?

Size-based impact
Change-based impact

Analysis of OBO ontology evolution and impact on materialisation.

How do ontology engineers understand the impact of ontology changes?

Analysis:

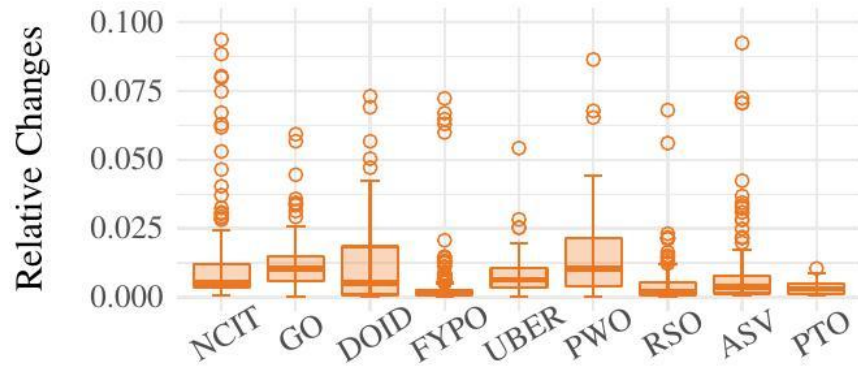
How do OBO ontologies evolve and what is the impact on the materialisation?

OBO ontologies and scope of study

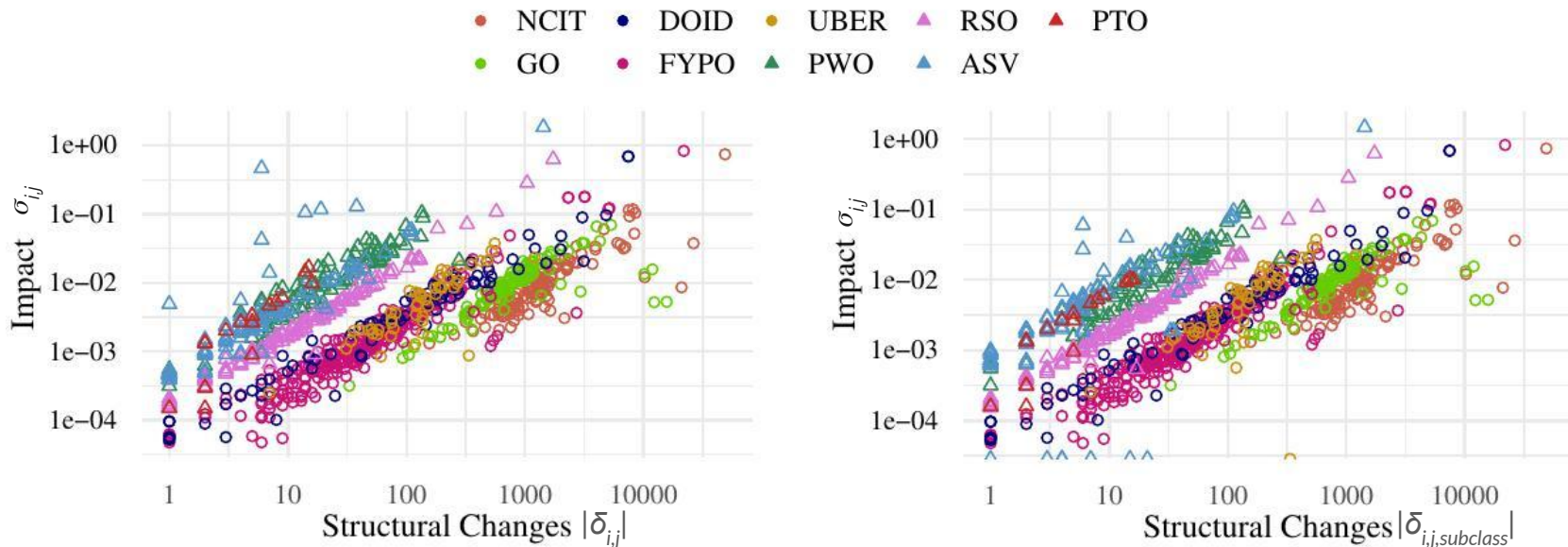
- 9 OBO ontologies from OBO Foundry, at least 100 versions: NCIT, GO, DOID, FYPO, UBERON, PWO, RSO, ASV, PTO
- EL++, only subclass relations between classes, no individuals.
- Analysis of changes and impact of changes on materialisation on macroscopic level.
- Types of changes according to COnto-Diff [1]:
Addition/Deletion/Move of concept, leaf, annotation
Move of subclass tree

[1] Hartung et al. (2013). COnto-Diff: generation of complex evolution mappings for life science ontologies, *Journal of Biomedical Informatic*. <https://doi.org/10.1016/j.jbi.2012.04.009>.

Change Analysis

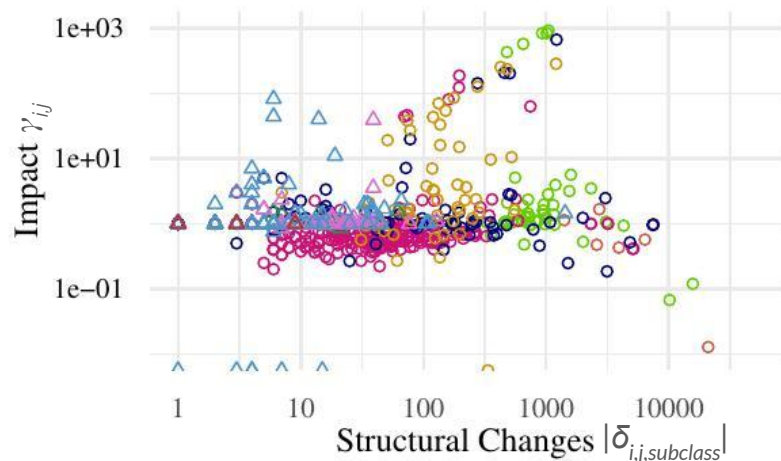
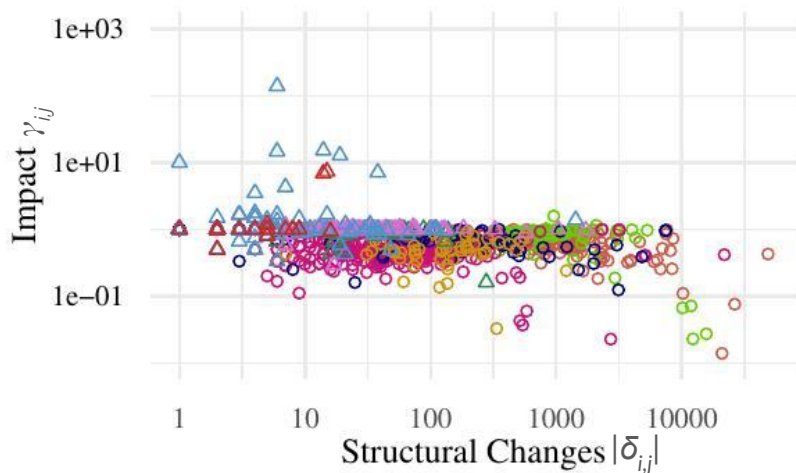


Size-based Impact $\sigma_{ij} = \frac{|\Delta_{ij}|}{|M_i \cap M_j|}$



Change-based Impact $\gamma_{ij} = \frac{|\Delta_{ij}|}{|\delta_{ij}|}$

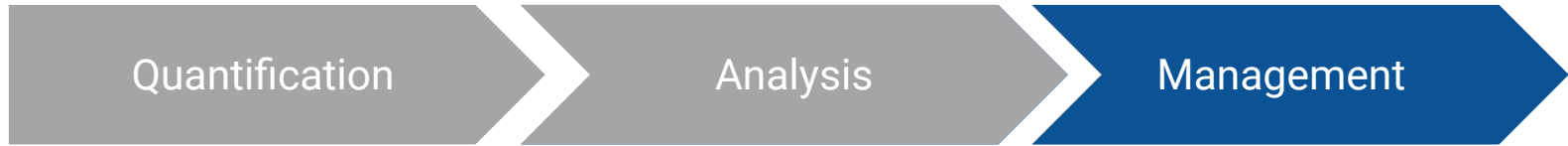
- NCIT
- DOID
- UBER
- ▲ RSO
- ▲ PTO
- GO
- FYPO
- ▲ PWO
- ▲ ASV



Ontology changes and their impact mostly affect the subclass hierarchy in OBO ontologies.



Materialisation



How can we capture the impact on the materialisation?

Change-based impact
Size-based impact

Analysis of OBO ontology evolution and impact on materialisation.

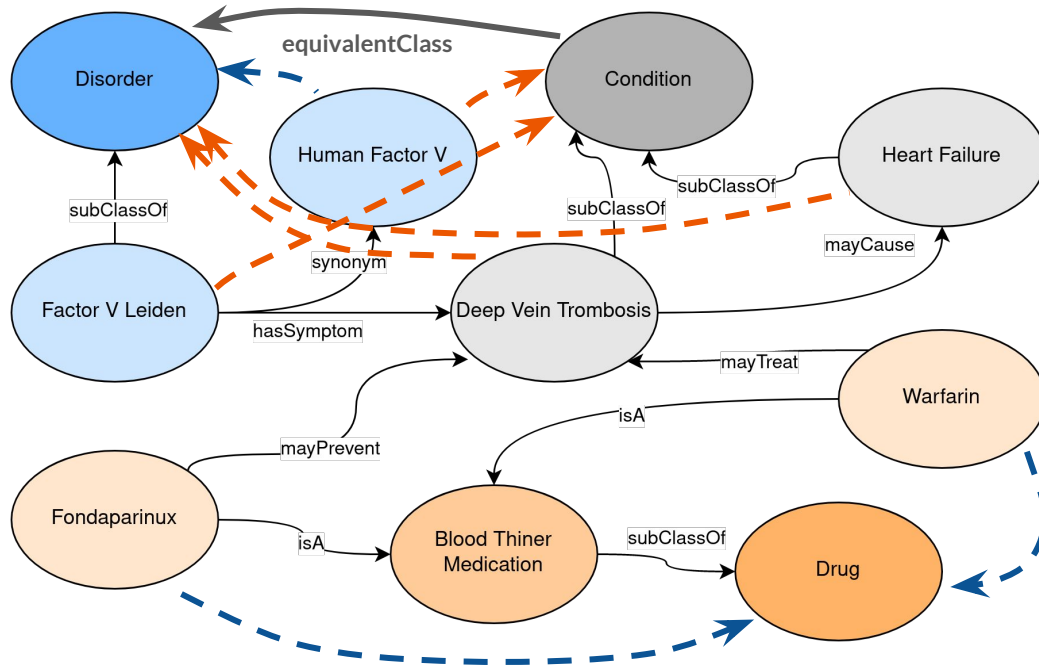
Change and impact on subclass hierarchy

How do ontology engineers understand the impact of ontology changes?

Management:

How do ontology engineers understand the impact of ontology evolution on the materialisation?

Can measures help engineers while applying changes?



Size-based impact
 $\sigma = 1.33$

Change-based impact
 $\gamma = 4$



Implementation of Materialisation Impact

- Requirements elicitation through online questionnaire
- Identified 10 requirements:
 - List of changes
 - Consistency
 - Measures and their change
 - Export functionality
 - Usage of colors

Pernisch et al. (2022). Visualising the effects of ontology changes and studying their understanding with ChImp. *Journal of Web Semantics*.
<https://doi.org/10.1016/j.websem.2022.100715>.

Implementation of Materialisation Impact

ChImp (Change Impact):

Changes

Previous Changes

- Added axiom: <AnnotationAssertion(rdfs:label <EggCheeseMix> "EggChee...>
- Added axiom: <Declaration(Class(<EggCheeseMix>))>
- Added axiom: <SubClassOf(<VegetableTopping> <PieFilling>)>
- Removed axiom: <EquivalentClasses(<PieFilling> <PizzaTopping>)>
- Added axiom: <EquivalentClasses(<PieFilling> <PizzaTopping>)>
- Added axiom: <SubClassOf(<DeepPanBase> <PieBase>)>

Impact

Reasoner active and the ontology is consistent

Size-based Impact 0.016529

We divide the number of changed inferred axioms by the unchanged inferred axioms. The unchanged inferred axioms can therefore be seen as the size of the materialization. This

Listview | Chartview

Primitive Metrics

Metric	Absolute	All Changes
Number of Axioms	814	+13
Number of Classes	104	+4
Number of Individuals	5	
Number of Properties	8	
Number of Object Properties	8	
Number of Datatype Properties	0	
Number of Annotations	11	
Number of Inverse Relations	6	
Number of Equivalent Class Relations	15	
Number of Inheritance Relations	266	+7

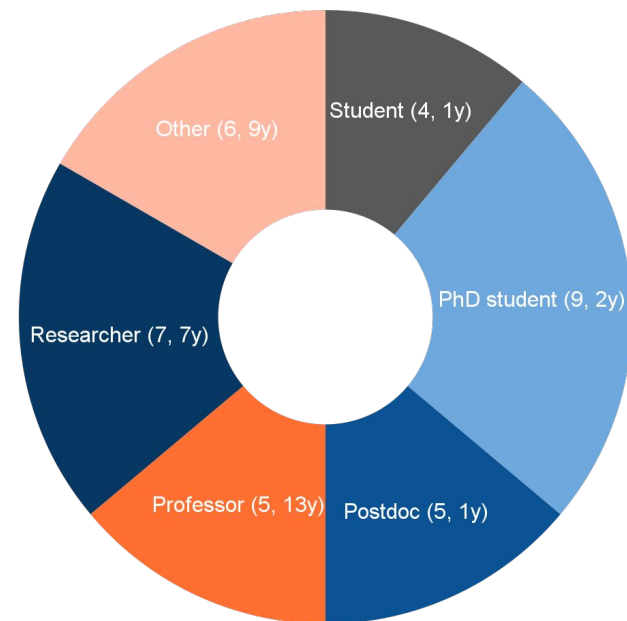
Composite Metrics

Metric	Absolute	All Changes
Annotation Richness	0.11	-0.00
Attribute Richness	0	
Average Population	0.05	-0.00
Class Property Ratio	13	+0.50
Datatype Property Ratio	0	
Inheritance Richness	2.56	-0.03
Inverse Property Ratio	0.75	
Object Property Ratio	1	
Property Class Ratio	0.08	-0.00
Relationship Richness	0.03	-0.00

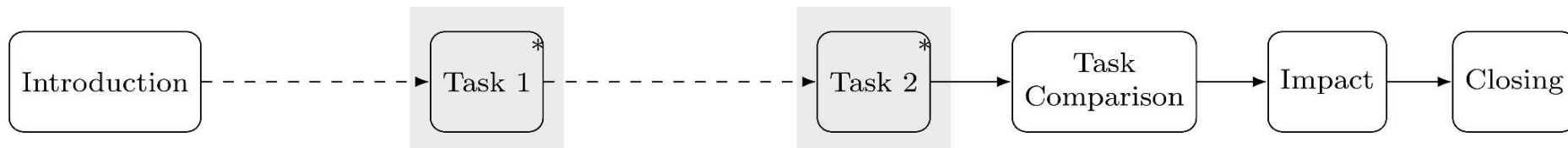
User Study

- Pizza ontology and 2 tasks to apply changes, one task with and the other without ChImp
- 36 Participants performed tasks locally on their own machine while following an online questionnaire
- Within-subject study design with 4 groups to minimise learning effect.

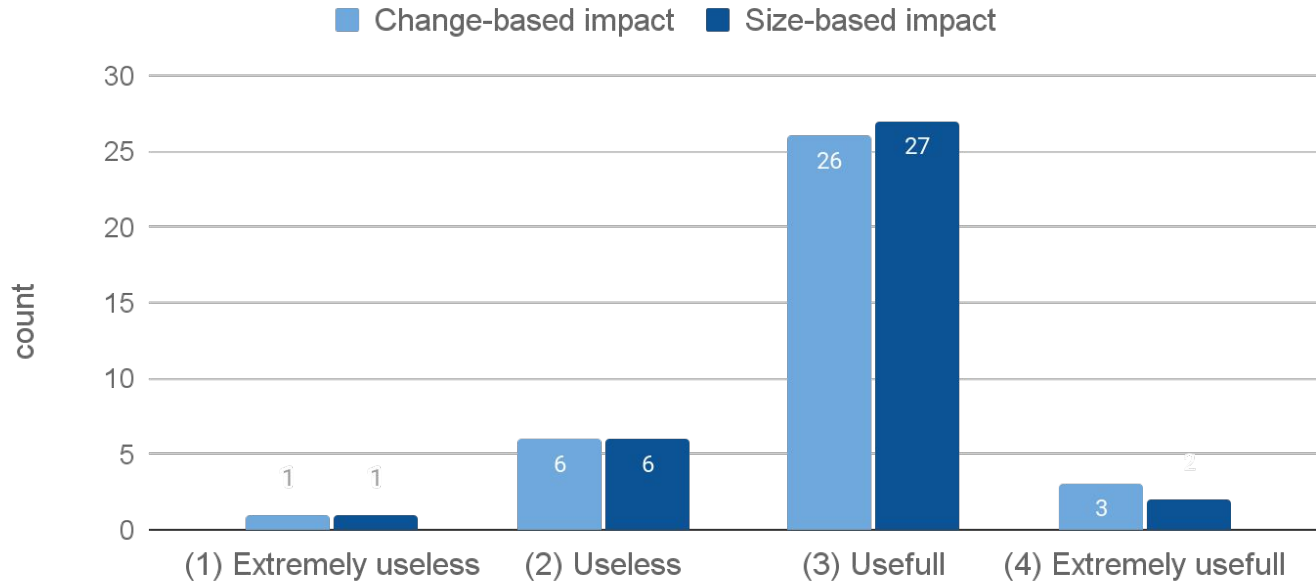
	Recorded	Used	G1	G2	G3	G4
Task 1	53	36	5	13	7	11
Task 2	37	25	4	7	6	8



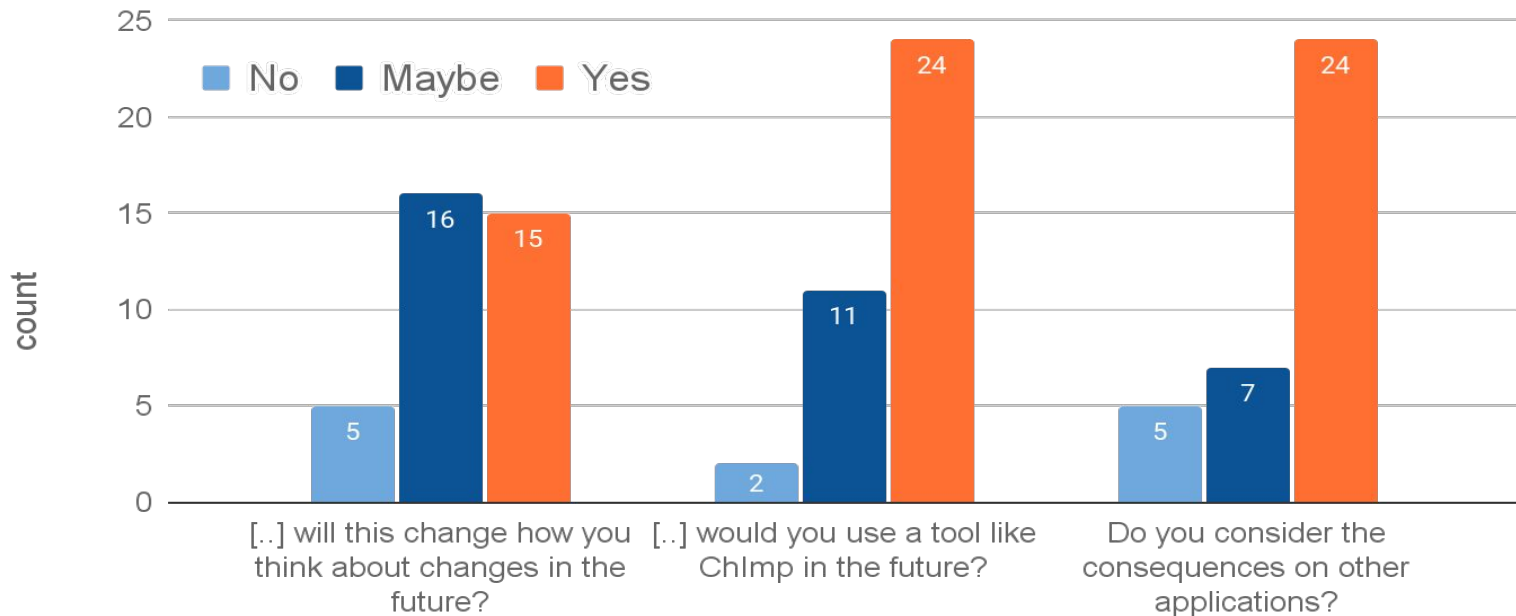
User Study



Are the materialization impact measures useful for ontology engineers?



Is ChImp helpful in thinking about consequences?



**ChImp is a useful tool to
communicate the impact of
changes on the ontology and
materialisation.**



Materialisation

Quantification

How can we capture the impact on the materialisation?

Change-based impact
Size-based impact

Analysis

Analysis of OBO ontology evolution and impact on materialisation.

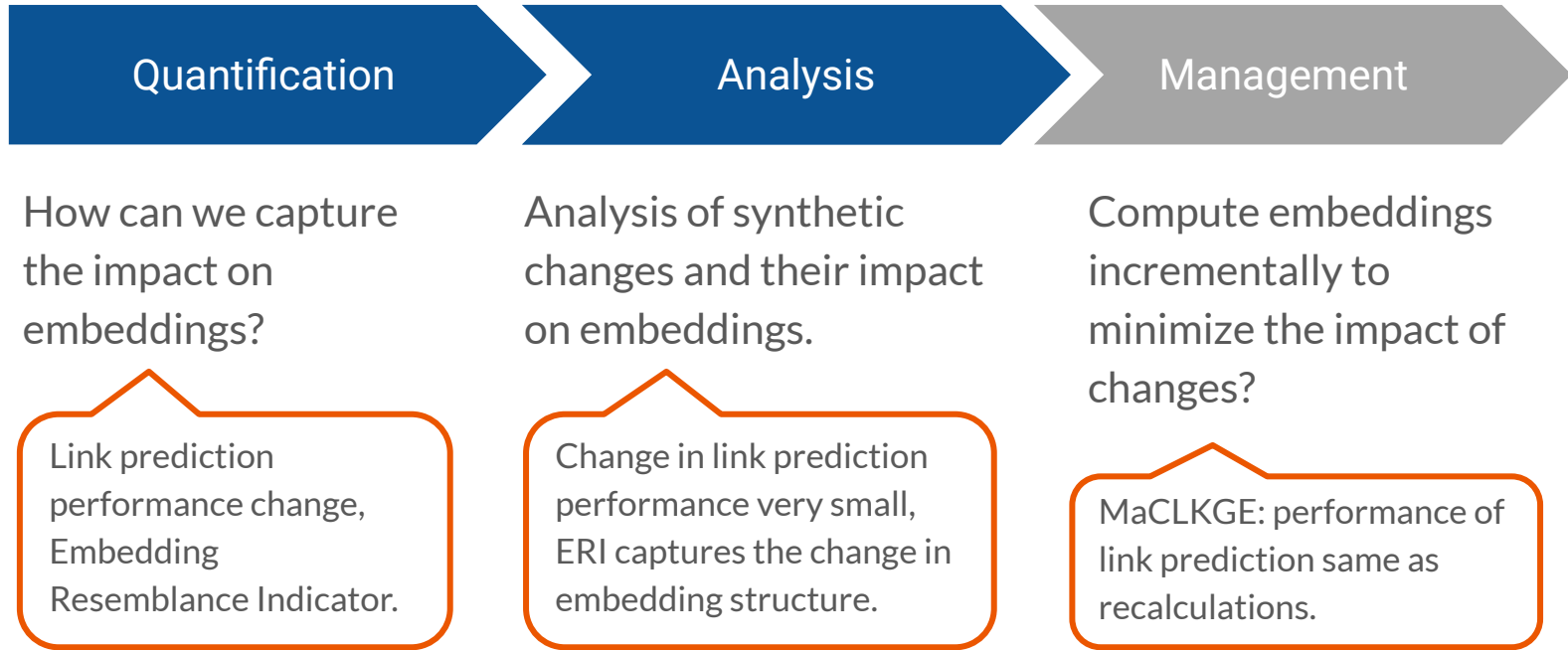
Change and impact on subclass hierarchy

Management

How do ontology engineers understand the impact of ontology changes?

ChImp plugin and measures were useful

Embeddings



Other Ongoing and Future Work



Ongoing and Future Work



Survey of ontology and KG measures and their usage in research.

Impact of changes on ML applications.

Analysis of concept changes in a robot environment.

Visualisations for ontology change summarisation.

Management framework for impact.

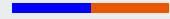
Knowledge Engineering and Evolution, and their Impact on AI

Input: ontologies, knowledge graphs
tables, documents



Applications: reasoning, embeddings
stream reasoning, machine learning

**Conclusion:
Analytical and empirical study
of knowledge engineering.**



Thank you for your attention.

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